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DOE/RL-93-23
Revision 0

N Springs Expedited Response Action Proposal

Date Published
January 1994

9413135.2009

United States
Department of Energy
P.O. Box 550
Richland, Washington 99352

Approved for Public Release

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EXECUTIVE SUMMARY

The release of large volumes of water to 1301-N and 1325-N liquid waste disposal facilities (LWDF) at the 100 N Area caused contaminants, principally strontium-90, to be carried toward the Columbia River through the groundwater. Since shutdown of the N Reactor, releases to the LWDF have been discontinued. The contamination is transported to the river as a result of the natural groundwater movement. The contaminated groundwater at N Springs flows into the river through seeps and springs along the river's edge. This expedited response action (ERA) is an interim action proposed to significantly reduce the flux of strontium-90 to the river.

The principal objective of the N Springs ERA Proposal is to evaluate alternatives and recommend an alternative or alternatives that best meet the selection criteria as prescribed by the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, including a demonstration of cost effectiveness. The methodology used for evaluation, cost analysis, and alternative recommendation is the engineering evaluation/cost analysis (EE/CA). Because final remediation of the contaminated groundwater beneath the 100 N Area is not a principal objective of the ERA, there is some flexibility in the scope of the ERA and the degree to which reduction of strontium-90 flux to the river is achieved. The EE/CA is to identify a system which optimizes the degree of benefit produced for the costs incurred.

Results from groundwater monitoring programs indicate that the principal contaminants in the groundwater downgradient of the 1301-N and 1325-N cribs are tritium and strontium-90. Other radionuclides are also present, but these are below regulatory limits.

A modeling effort was conducted prior to the EE/CA for different purposes. The results from this effort are used in this proposal; however, because the model was constructed with different objectives, some uncertainties are inherent in the evaluation of the alternatives using the model.

The preferred alternative should provide a high degree of protectiveness balanced with acceptable risks and reasonable costs. However, as a result of the additional analysis performed in response to regulatory comments, it is now concluded that a preferred alternative cannot be confidently recommended in view of the technical and cost uncertainties of both alternatives. Therefore, both the slurry wall and the pump and treat alternatives are recommended as preferred alternatives. Additional information may be needed prior to implementing a single preferred action. The following activities are proposed to gather this information:

- Time consistent groundwater and spring sampling - All wells associated with the N Springs area and the strontium-90 plume, including the wells at the springs, should be sampled at the same time to allow construction of representative contaminant plume maps. This information will be used to construct the groundwater model.

- Additional groundwater flow and contaminant transport modeling for the alternatives - The model will be constructed specifically for the evaluation of these alternatives using current N Springs area conditions. The model will be used to evaluate performance of the alternatives including hydraulic control to optimize elements of each alternative, such as wall length and placement, well spacing, and well pumping rates, and to determine remediation time frames.

- Subsurface characterization - Two borings will be drilled to define the confining layer depth and thickness. Sediment samples from the aquifer will be collected to determine aquifer physical parameters including strontium-90 sorption characteristics.

- Slurry wall implementability test - A test panel using the deep soil mixture equipment will be constructed in a clean zone in the 100 N Area. Slurry formulations consistent with the N Springs area water and soils will be developed. Following placement of the test panel, the panel will be drilled to determine if the panel meets permeability criteria.

- Treatability studies for ion exchange and reverse osmosis treatment systems - A bench-scale treatability study will be conducted for the ion exchange treatment system. Information will be generated (in coordination with other treatability tests being conducted on-site) on appropriate ion exchange media, media loading, waste generation, and costs. A pilot-scale reverse osmosis treatability test will be conducted in the field to determine an acceptable membrane, membrane loading, waste generation, waste water treatment, and cost.

- Wetlands regulatory review/assessment - A regulatory review will be conducted to determine the requirements needed to conduct the ERA near the river. Wetlands, floodplain, and Wild and Scenic Rivers Act regulations will be reviewed to identify requirements; appropriate federal and state agencies will be contacted if necessary. If warranted, a wetlands assessment will be conducted prior to alternative implementation. This issue directly affects the location, size, effectiveness, and cost of the slurry wall.

- Endangered vegetation study - A study of endangered species located at the N Springs area will be conducted to identify potential impacts.

- Additional analysis and refinement of costs - The cost estimates will be refined based on the additional information gathered in the other activities.

The information gathered from the above activities will be used to implement the preferred alternative. This preferred alternative will continue through the design phase and ultimately be implemented.

ACRONYMS

ALARA	as low as reasonably achievable
ARAR	applicable or relevant and appropriate requirements
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COPC	chemicals of potential concern
DOE	U.S. Department of Energy
DST	double-shell tanks
Ecology	Washington State Department of Ecology
EE/CA	engineering evaluation/cost analysis
EPA	U.S. Environmental Protection Agency
ERA	expedited response action
ERDF	Environmental Restoration Disposal Facility
HCRC	Hanford Cultural Resources Clearance
HCRL	Hanford Cultural Resources Laboratory
IRM	interim response measure
FS	feasibility study
LWDF	liquid waste disposal facility
MCL	maximum contaminant level
NCP	National Contingency Plan
NERP	National Environmental Research Park
NPDES	National Pollutant Discharge Elimination System
O&M	operating and maintenance
ORNL	Oak Ridge National Laboratory
RAO	removal action objective
RCRA	Resource Conservation and Recovery Act
R&D	research and development
RL	Richland Operations Office
SARA	Superfund Amendments and Reauthorization Act
TBC	to-be-considered
Tri-Party Agreement	Hanford Federal Facility Agreement and Consent Order
WHC	Westinghouse Hanford Company

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1.0 INTRODUCTION

Since signing the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) in 1989 (Ecology et al. 1989), the parties to the agreement have recognized the need to modify the approach to conducting investigations, studies, and cleanup actions at Hanford with a goal of maximizing efficiency, optimizing use of limited resources, and achieving cleanup in the earliest possible time frame. To implement this approach, the parties have jointly developed the *Hanford Past-Practice Strategy* (DOE-RL 1991a). The principles of the strategy are embodied in the *Hanford Federal Facility Agreement and Consent Order Change Package* (Ecology et al. 1991).

The strategy defines a non-time-critical expedited response action (ERA) as a response action "needed to abate a threat to human health or welfare or the environment where sufficient time exists for formal planning prior to initiation of response. A non-time-critical ERA may also address a situation encompassing levels of contamination which do not pose an immediate danger or threat to human health or welfare or the environment, but which might justify a response action by the need to control the spread of contamination, to abate a threat, or provide for a greater overall cost effectiveness by more timely response." In accordance with the past-practice strategy, the U.S. Department of Energy (DOE) proposes to conduct an ERA at the N Springs, located in the Hanford 100 N Area, to substantially reduce the strontium-90 transport into the river through the groundwater pathway.

The N Springs ERA is part of the Senior Executive Committee Agreement on resolution of the Tri-Party Agreement Milestone M-14 Change Request Dispute dated January 8, 1993 (Ecology et al. 1993). The N Springs ERA is a joint agreement by the parties to the Tri-Party Agreement. The purpose of this ERA proposal is to provide sufficient information to select a preferred alternative at N Springs. The nature of an ERA requires that alternatives developed for the ERA be field ready; therefore, all the technologies proposed for the ERA should be capable of addressing the circumstances at N Springs. A comparison of these alternatives is made based on protectiveness, cost, technical feasibility, and institutional considerations to arrive at a preferred alternative. Following the selection of an alternative, a design phase will be conducted; the design phase will include a detailed look at design parameters, performance specifications, and costs of the selected alternative. Testing will be conducted as required to generate design data.

1.1 BACKGROUND

Past-practices in the 100 N Area have resulted in contamination of the soils and underlying groundwater in the reactor vicinity. The release of large volumes of water to the 1301-N and 1325-N liquid waste disposal facilities (LWDF) at the 100 N Area caused contaminants, principally strontium-90, to be carried toward the Columbia River through the groundwater. Since shutdown of the N Reactor, the releases to the LWDF have been discontinued (see Section 2.2.3). The contamination is transported to the river as a result of the natural groundwater movement. The contaminated groundwater at N Springs flows into the river through seeps and springs along the river's edge and is rapidly diluted to very low levels. N Springs represents a significant pathway for strontium-90 release into the river. The ERA is proposed to substantially reduce the flux of strontium-90 migration into the river.

This ERA meets the criteria as defined in the *Hanford Past-Practice Strategy* (DOE-RL 1991a) and as detailed in the *Site Selection Process for Expedited Response Actions at the Hanford Site* (Gustafson 1991). The ERA will be conducted as a non-time-critical removal action under the regulatory authority as defined in Title 40 Code of Federal Regulations (CFR) 300.415 and as described in the *N Springs Expedited Response Action Project Plan* (IT Corporation 1992).

In accordance with the past-practice strategy and the requirements of removal actions under 40 CFR 300.415, the ERA does not necessarily constitute the final remedial action for the 100 N Area operable unit(s), but will, to the extent practicable, contribute to the efficient performance of the final remedial actions with respect to the contaminant release(s). In accordance with 40 CFR 300.415(i), removal actions shall, to the extent practicable considering the exigencies of the situation, attain applicable or relevant and appropriate requirements (ARAR).

The principal objective of the N Springs ERA Proposal is to evaluate alternatives and recommend a single alternative or multiple alternatives that best meet the selection criteria as prescribed by Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), including a demonstration of cost effectiveness. The methodology used for evaluation, cost analysis, and alternative recommendation is referred to as an engineering evaluation/cost analysis (EE/CA). Because final remediation of the contaminated groundwater beneath the 100 N Area is not a principal objective of the ERA, there is some flexibility in the scope of the ERA and the degree to which reduction of strontium-90 contamination to the river is achieved. The EE/CA, which is conducted as part of the ERA proposal preparation, attempts to identify an ERA system which optimizes the degree of benefit produced for the costs incurred.

1.2 SCOPE

The scope of the ERA proposal is to identify, screen, and compare removal action alternatives that eliminate or substantially reduce the flux of strontium-90 to the river. The goal of the proposal is a recommended cost effective alternative that meets the ERA objectives. The proposal includes a summary of new and existing information to select an alternative. Additional information concerning costs and performance specifications will be collected during the design phase.

The CERCLA limits fund-financed removal actions to a 24-month duration and $2 million in costs. While these limitations do not apply to federal actions, the ERA should be reviewed at an appropriate time after implementation for conversion to an interim response action (IRM). The ERA should, to the extent practical, contribute to the effective performance of any final actions. Therefore, the ERA should be reevaluated as planning in the 100 N Area proceeds to ensure compatibility with future actions.

2.0 SITE DESCRIPTION

This section provides a background discussion of the 100 N Area physical setting and the nature and extent of contamination to be addressed by the N Springs ERA.

2.1 PHYSICAL SETTING

The Hanford Site lies within the semi-arid Pasco Basin of the Columbia Plateau in southeastern Washington State. The Hanford Site occupies an area of about 560 mi^2 (1,450 km^2) north of the confluence of the Snake and Yakima Rivers with the Columbia River. The Columbia River flows through the northern part of the site and, on turning south, forms the eastern site boundary. Rattlesnake Mountain, the Yakima Ridge, and Umtanum Ridge form the southwestern and western boundaries while the Saddle Mountains form the northern boundary of the Hanford Site. Two small east-west trending ridges, Gable Mountain and Gable Butte, rise above the plateau of the central part of the Hanford Site. The cities of Richland, Pasco, and Kennewick (Tri-Cities) are the nearest population centers to the Hanford Site. (See Figure 2-1.)

The subsections below describe the physical setting of the N Springs area, including both a discussion of the natural characteristics of the site and the human-induced influences on the site.

2.1.1 Location

The N Springs are a series of springs and seeps located along the southern edge of the Columbia River in and adjacent to the 100 N Area (Figure 2-2). The N Springs ERA site is located west and north of the 1301-N and 1325-N cribs and is bordered by the Columbia River, the 100 N Area, and the 600 Area. The N Reactor (and associated support facilities), located in the 100 N Area, was operated as a dual production reactor (plutonium and by-product steam for electricity generation) from 1963 until 1987. The City of Richland is approximately 27 air or 38 river mi (43 air or 61 river km) south of the 100 N Area. The N Springs are included in the 100-NR-2 Operable Unit.

2.1.2 Topography

The topography of the 100 N Area ranges in elevation from approximately 387 ft (118 m) amsl at the Columbia River to approximately 460 ft (140 m) amsl on the east side of the area. Some of the area has been reworked as part of construction of the reactor building and related facilities and is relatively flat with an elevation of approximately 450 ft (137 m) amsl. The slope along the river bank is steep with gradients of at least 15%. Elevations within the N Springs ERA site range from approximately 387 ft (118 m) amsl along the river to approximately 490 ft (150 m) amsl in unimproved areas. The surrounding terrain is hummocky, probably as a result of catastrophic flooding associated with Pleistocene glaciation.

2.1.3 Meteorology and Air Quality

The Hanford Site weather is monitored at the Hanford Meteorology Station and at remote stations throughout the site. Station 13 of the Hanford Telemetry Network is located in the 100 N Area.

The climate of the Hanford Site is semi-arid and is greatly affected by the Cascade Mountains to the west. The Hanford Site receives an average of 6.3 in (16 cm) of precipitation annually. The precipitation falls mainly in the winter months, with nearly half of the annual precipitation falling between November and February. Precipitation of 0.5 in (1.3 cm) or more falling within a 24-hour period occurs only twice per year on the average. Instances of 1.0 in (2.5 cm) or more of precipitation within a 24-hour period are infrequent, with only four occurrences between 1946 and 1980 (Cushing 1991).

Winter monthly average snowfall varies from 5.3 in (13.5 cm) in January to 0.3 in (0.8 cm) in March. The record snowfall of 24.4 in (62 cm) occurred in February 1916. During the months of December through February, snowfall accounts for about 38% of all precipitation (Cushing 1991).

The average annual relative humidity between 1946 and 1980 was 54.4%. Humidity is higher in winter months than during the summer (Cushing 1991).

The Cascade Mountains serve as a source of cold air drainage and have a considerable effect on the winds at Hanford. The gravity drainage, plus topographic channeling, results in northwest to west-northwest prevailing wind directions. The average mean monthly speed for the period 1945 to 1980 was 7.7 mi/h (12.4 km/h) with monthly means ranging from 6.1 mi/h (9.8 km/h) in December to 9.2 mi/h (14.8 km/h) in June (Stone et al. 1983). Peak gust speeds range from 63 to 80 mi/h (101 to 129 km/h) and are generally associated with southwest to west-southwest winds (Stone et al. 1983).

Daily maximum and minimum temperatures range from an average of 36°F (2°C) in January to 95°F (35°C) in late July. There are, on average, 55 days during the summer months with maximum temperatures >90°F (32°C). From mid-November through mid-March, minimum temperatures average <32°F (0°C) with the minimum in early January averaging 21°F (-6°C). The record maximum temperature is 115°F (46°C) and the record minimum is -27°F (-32.8°C) (Cushing 1991).

The actual annual evapotranspiration under current conditions for the Hanford Site is estimated to be 6.1 in (15.5 cm) (Bauer and Vaccaro 1990).

2.1.4 Soils

Hajek (1966) lists and describes 15 different soil types on the Hanford Site, ranging from sand to silty sandy loam. Soils in the 100 N Area are described as either a sandy or stony loam. The sandy loam described by Hajek (1966) as surface soil is dark colored, while subsoil is dark-grayish-brown, medium textured, underlain by gravelly material. The stony loam is described as similar to the sandy loam; however, the stony loam contains gravel to boulder-sized debris released from melting glaciers.

2.1.5 Geology

The following discussions are based on all of the data available for the 100 N Area. The geologic and hydrologic discussions are primarily from Hartman and Lindsey (1993), which presents a detailed description of the 100 N Area hydrogeology.

2.1.5.1 Structure. Structurally, the Hanford Site lies in the eastern Yakima Fold Belt. This belt consists of a series of segmented, narrow, asymmetric, and generally east-west trending anticlines. Between these anticlines lie broad, shallow synclines. The Hanford Site is situated in the Pasco Basin, a structural basin. Within the Pasco Basin, the Gable Mountain anticline separates the Wahluke and Cold Creek synclines; the 100 N Area is on the north limb of the Wahluke syncline. South of the 100 N Area, basalt flows and the older units of the Ringold Formation dip steeply to the north. Beneath and to the north of the area, those same strata dip at shallow angles (about 5°) to the south (Lindberg 1993a). The structural setting of south-central Washington and the Hanford Site is discussed in DOE (1988) and Reidel et al. (1989, 1992, 1993).

2.1.5.2 Stratigraphy. The 100 N Area is underlain by: (1) Pleistocene-aged (<2 million years old) cataclysmic flood deposits of the Hanford formation, (2) late Miocene to middle Pliocene-aged (<8.5 to >3.4 million years old) alluvial-lacustrine deposits of the Ringold Formation, and (3) basalts of the Miocene-aged (17 to 6.5 million years old) Columbia River Basalt Group (Figure 2-3). Local surficial Holocene deposits are also found. The uppermost basalt unit beneath the 100 N Area is the 10.5 million year old Elephant Mountain Member of the Saddle Mountains Basalt. Only two boreholes penetrate to the Elephant Mountain Member at the site. Detailed discussions of the Saddle Mountains Basalt can be found in Reidel and Fecht (1981).

2.1.5.2.1 Ringold Formation. The Ringold Formation in the northern part of the Hanford Site consists of a mix of fluvial gravels, fluvial sands, overbank deposits, paleosols, and lake deposits (Lindsey 1991, 1992). Characteristics of these deposits, also referred to as facies associations, and Ringold stratigraphic subdivisions are described for the Hanford Site in Lindsey (1991) and Reidel et al. (1993). Lindsey (1992), Lindberg (1993a, b), and Lindsey and Jaeger (1993) describe the Ringold Formation in the area surrounding the 100 N Area. The Ringold Formation ranges from 450 to 494 ft (136 to 150 m) thick in the only two boreholes in the 100 N Area that reach the top of the basalts (Hartman and Lindsey 1993).

Fluvial gravel dominated deposits of unit A form the base of the Ringold Formation in the 100 N Area as observed in boreholes 699-81-62 and 699-84-59. Unit A ranges from 12 to 25 ft (3.6 to 7.6 m) thick in these two boreholes. The unit is not present beneath the 100 H Area (Lindsey and Jaeger 1993), nor in boreholes north of the Columbia River on the Wahluke Slope. It is not known where unit A pinches out between these locations and the 100 N Area (Hartman and Lindsey 1993).

Unit A is overlain in succession by the lower mud unit (approximately 100 ft [30 m] thick), unit B (66 to 71 ft [20 to 21.5 m] thick), a paleosol-overbank interval (125 to 141 ft [38 to 43 m] thick), unit C (10 to 15 ft [3 to 4.5 m] thick), another paleosol-overbank interval (55 to 96 ft [17 to 29 m] thick), and unit E (17 to 65 ft [5.2 to 20 m] thick). The lower mud unit consists of a lower paleosol-dominated interval and an upper lake deposit-dominated interval. Units B and C are both dominated by fluvial sands with lesser, but still common, silty overbank deposits and minor fluvial gravels. The paleosol-overbank intervals between units B and C and between units C and E are dominated by silt-rich deposits that contain locally abundant pedogenic carbonate development and minor sand interbeds (generally <10 ft [3 m] thick). The top of the paleosol/overbank interval beneath unit E ranges from 349 to 359 ft (106 to 109 m) amsl in the 100 N Area. Fluvial gravels form the uppermost Ringold unit in the area, unit E. The gravels of unit E are continuous beneath the entire 100 N site (Hartman and Lindsey 1993).

2.1.5.2.2 Hanford Formation. Gravels dominate the Hanford formation in the 100 N Area. It is 19 to 77 ft (5.8 to 23 m) thick. These gravels are typical of the gravel-dominated facies of the Hanford formation, based on examination of borehole samples and gravel pits in the area. Characteristics of these gravels across the region are discussed in Baker et al. (1991) and Reidel et al. (1993). Other Hanford formation facies (sand-dominated and silt-dominated) appear to be lacking in the 100 N Area.

Two main lithologies comprise the gravel-dominated facies in the 100 N Area: (1) a pebble-cobble unit and (2) a cobble-boulder unit. Pebble-cobble lithologies dominate the Hanford formation in the 100 N Area and occur in all the boreholes studied. These deposits generally are similar to Hanford formation gravels elsewhere in the 100 Area. They are well stratified, uncemented, clast supported, and have a sand-rich matrix. Open-framework textures, which are typical of the gravel facies on a regional scale, are absent in the few shallow gravel pits found in the northern part of the Hanford Site. However, the presence of this texture cannot be dismissed because it is so common elsewhere. Borehole logs and the few outcrops available suggest silt layers are rare to absent, although experience elsewhere on the Hanford Site suggests they may be present locally (Hartman and Lindsey 1993).

The cobble-boulder unit occurs throughout most of the 100 N Area at or near the top of the Hanford formation. Where present, this unit is usually between 10 and 20 ft (3 and 6 m) thick, although it has been observed at up to 49 ft (15 m) thick. Reconnaissance mapping and interpretation of borehole log descriptions indicate clasts at least 3 ft (1 m) in diameter are common. Except for increased clast size, the cobble-boulder unit displays characteristics typical of other occurrences of the gravel facies. It is uncemented and generally clast supported, has a sand to granule matrix, and open-framework textures are common. The boulder-rich stratum in the 100 N Area lies at the northeastern end of an elongate cobble-boulder tract that extends to the southwest along the Columbia River through the 100 K (Lindberg 1993b) and 100 B/C (Lindberg 1993a) Areas.

Clastic dikes are a common feature of the Hanford formation throughout the region (Black 1979). The few available outcrops and the dominance of gravelly lithologies found in the Hanford formation suggests clastic dikes are unlikely in the 100 N Area.

2.1.5.2.3 Hanford-Ringold Contact. Hanford formation gravels overlie Ringold Formation gravels throughout the 100 N Area. This contact is irregular and was formed by post-Ringold erosion, probably associated with Pleistocene cataclysmic flooding. Several criteria are used to differentiate the two units.

1) The sand fraction in Hanford gravels generally contains <40% basalt; Ringold deposits generally contain >25% basalt.

2) Hanford gravels may display salt and pepper and gray coloring while Ringold gravels are generally more oxidized and red-brown to yellow-red in color.

3) Ringold gravels generally are consolidated and cementation may be well developed locally. Consequently, drilling rates tend to be slower in the Ringold Formation than in the Hanford formation.

Lindsey and Jaeger (1993) describe the presence of a zone at the base of the Hanford formation that is rich in Ringold-like lithologies. Where it is found this zone is interpreted to be part of the Hanford formation. This zone is interpreted to consist of ripped-up and redeposited Ringold Formation material. While these rip-up horizons tend to be localized, they can make identification of the contact difficult. Where this occurs as many criteria as possible are used to best estimate the position of the contact. In these situations it only may be possible to approximate the top of the Ringold Formation (Hartman and Lindsey 1993).

2.1.5.2.4 Holocene Deposits. Holocene eolian deposits locally overlie the Hanford formation in the 100 N Area. These deposits are typically heterogenous and poorly mixed and were derived primarily from reworked Hanford formation sediments.

2.1.6 Physical Properties

The vadose zone is 65 to 75 ft (20 to 23 m) thick beneath most of the 100 N Area. Soil moisture data for the 100 N Area are limited. Moisture content in wells 199-N-71 through 199-N-77 ranged from 1 to 3% (Hartman 1992, 1993).

Samples collected during drilling of well 199-N-80 were analyzed for physical properties including grain size, bulk density, specific gravity, saturated hydraulic conductivity, calcium carbonate content, and moisture retention. Data from the three vadose zone samples are summarized in Hartman and Lindsey (1993).

Ten vadose zone sites near the river were sampled for laboratory testing as input to a computer model (Connelly et al. 1991). The sites were also equipped with permeameters. The data were used to construct moisture characteristic curves for the unsaturated sediments. Hydrologic parameters derived from the curves are listed in Connelly et al. (1991).

2.1.7 Hydrogeology

The 100 N Area is underlain by the vadose zone, an unconfined aquifer, a series of confined aquifers in the unconsolidated sediments, and a series of confined aquifers in the basalts and interbeds (see Figure 2-3). The unconsolidated sediments of the Ringold Formation contain a series of producing and confining layers. The saturated, unconsolidated sediments are called the "uppermost aquifer system." The unconfined portion of the system has been defined as the "uppermost aquifer" (Hartman 1993). However, the degree of isolation provided by the confining beds within the Ringold Formation is not well known.

2.1.7.1 Vadose Zone. The vadose zone beneath the 100 N Area is primarily comprised of unconsolidated sediments of the Hanford formation. This highly permeable unit consists of mainly cobbles, boulders, pebbles, and coarse sand. Drilling data indicate that isolated lenses of silty sand and gravel are also present. The vadose zone also includes the top few feet of the Ringold Formation in some parts of the 100 N Area. The unsaturated Ringold sediments are similar to the Hanford formation: sands, gravels, and cobbles, with varying fractions of silt. The vadose zone is 65 to 75 ft (20 to 23 m) thick beneath most of the 100 N Area (Hartman and Lindsey 1993).

Some perched water was noted during drilling of well 199-N-35 at a depth of approximately 30 ft (9 m). Well 199-N-35 is located immediately adjacent to the 1325-N crib, and it was installed after effluent disposal to that unit had begun. This well was installed along with wells numbered between 199-N-27 to 199-N-52 between 1983 and 1985 to monitor groundwater around the 1325-N LWDF. No other perched groundwater was noted in the 100 N Area drilling logs (Hartman and Lindsey 1993).

2.1.7.1.1 Hydraulic Properties. Connelly et al. (1991) collected soil samples from the unsaturatated zone for estimating saturated hydraulic conductivities for the vadose zone. These estimates ranged from 1.4 to 170 ft/d (0.43 to 52 m/d). Connelly et al. (1991) compared these test data with values obtained from Brown and Rowe (1960) and Pratt (1985). Connelly et al. (1991) determined that a vertical hydraulic conductivity value of 3 ft/d (1 m/d) was representative of the vadose zone soils in the area of the LWDF. The values reported in Connelly et al. (1991) were somewhat higher than those reported in the other two studies which were conducted in the field. Connelly et al. (1991) suggested that the difference may be due to "realignment of fine soil and precipitate particles and a decrease of porosity ... until an equilibrium value is attained".
These factors were not present in the Connelly et al. (1991) tests.

2.1.7.2 Uppermost Aquifer. The uppermost aquifer beneath the 100 N Area is an unconfined sand and gravel unit in the Ringold Formation (unit E in Section 2.1.5.2.1; see Figure 2-3). In some locations the bottom portion of the Hanford formation was also saturated when groundwater mounds were present (1964-1989). The base of the aquifer is believed to be a laterally continuous fine-grained unit of paleosols and overbank deposits. Sediments of this unit are believed to range from clay and silt to sand. Most of the wells in the 100 N Area were completed at the water table; therefore the thickness of the fine-grained unit is not known precisely at all locations (Hartman and Lindsey 1993).

The unconfined aquifer is approximately 40 to 50 ft (12 to 15 m) thick beneath the 100 N Area. Information on the 100 N Area hydrogeology is summarized from well log data, aquifer test results, water table maps, and published reports (Hartman and Lindsey 1993).

2.1.7.2.1 Hydraulic Properties. Most of the aquifer tests in the 100 N Area have been short-term pumping tests (often without observation wells) or slug tests. All were conducted in the uppermost aquifer. Transmissivity estimates range from 200 to 200,000 ft^2/d (18 to 18,000 m^2/d) (Hartman and Lindsey 1993). A large range of transmissivity would be expected in the 100 N Area because the geology is heterogeneous. However, the breadth of this range of estimates may also reflect poorly-conducted tests; in most cases, data were collected during well development and aquifer testing was not the primary objective. Gilmore et al. (1992) attempted to narrow the range of hydraulic property estimates using three methods: (1) reanalysis of pumping test data; (2) the Ferris method, using river/aquifer responses; and (3) estimates based on the groundwater flow equation and river level fluctuations. A representative range of transmissivity of the uppermost aquifer is 1,000 to 6,000 ft^2/d (90 to 540 m^2/d) throughout most of the 100 N Area. Wells in the northwest (199-N-14 and 199-N-51) seem to show a higher transmissivity (up to 20,000 ft^2/d [1,800 m^2/d]). These values correspond to horizontal hydraulic conductivity of 50 to 300 ft/d (0.02 to 0.11 cm/s); 1,000 ft/d (0.35 cm/s) in the northwest. Specific yield is estimated at 0.1 to 0.3 (Hartman and Lindsey 1993).

Split-spoon samples from the uppermost aquifer in well 199-N-80 were analyzed in the laboratory for vertical hydraulic conductivity. Results ranged from 0.1 to 70 ft/d (3.5×10^{-5} to 0.02 cm/s) (Hartman and Lindsey 1993).

2.1.7.2.2 Groundwater Flow. Unconfined groundwater in the northern Hanford Site generally flows to the north and east. Groundwater discharges to the Columbia River through most of the year, except in the area west of the 100 B Area, where the river appears to recharge the aquifer (Hartman and Lindsey 1993).

Groundwater in the uppermost aquifer beneath the 100 N Area flows mainly to the north and northwest. Figure 2-4 is a water table map constructed of an average of monthly water levels between June 1992 and May 1993. Averaged data were used to smooth out variations due to river stage changes. Groundwater is inferred to flow toward the river beneath most of the area, and to the north beneath the 1325-N LWDF. Groundwater discharges to the river through riverbank springs and, presumably, through the sediments underwater (Hartman and Lindsey 1993).

The 100 N Area water table map for May 1991 (Figure 2-5) illustrates the water table when the Columbia River ran at high stage for several months. When river stage is high, water flows out of the river into the aquifer. Gilmore et al. (1990, 1991) studied the effects of river stage on the aquifer near the 1301-N LWDF. The study demonstrated that the effects of seasonal river stage changes were noticeable up to 1,000 ft (300 m) inland and daily river-level fluctuations affected groundwater levels up to 750 ft (230 m) inland.

Groundwater levels in the 100 N Area and across the Hanford Site have varied through time because of artificial recharge from liquid waste disposal operations. The water table continues to decline at a slow rate and has nearly returned to a stable level. Changes in water levels in response to changes in river stage are still evident. There may be small groundwater mounds due to recharge from the backwash lake and the sewage lagoons, but there are no wells to measure water levels around these sites (Hartman and Lindsey 1993).

Changes in water levels caused by waste disposal have affected groundwater flow directions in the unconfined aquifer. Groundwater mounds formed beneath the 1301-N, 1325-N, and 1324-N/NA sites at various times in the history of waste disposal at the 100 N Area. Locally, groundwater flowed outward from these mounds. There are no head data from the years before waste discharge to the sediments at the 100 N Area began. The natural groundwater flow direction was probably to the north and northwest, toward the river (Hartman and Lindsey 1993).

Vertical groundwater gradients are not well defined in the 100 N Area. Well 199-N-67 is completed at the water table and well 199-N-69 is completed at the base of the aquifer about 6 m (20 ft) below the water table. The vertical gradient between 199-N-67 and 199-N-69 appears to be negligible. Well 199-N-39 is completed at the water table, and well 199-N-70 is completed at the base of the aquifer about 20 ft (6 m) below the water table near the 1325-N LWDF. The vertical gradient between wells 199-N-39 and 199-N-70 also appears to be negligible (Hartman and Lindsey 1993).

There appears to be an observable upward vertical gradient adjacent to the river in the 100 N Area. Data from the unconfined wells in the 199-N-8 well cluster are sparse except for well 199-N-8S, which is completed slightly below the average water table. Gilmore et al. (1991) provides hydrographs for well 199-N-8S and the Columbia River at the 100 N Area, slightly upstream from well 199-N-8S. Well 199-N-8S generally has a higher head than the river, except during times of high river level, when the gradient is reversed (Hartman and Lindsey 1993).

2.1.7.2.3 N Springs. Riverbank springs in the 100 N Area are known as "N Springs." The springs are a series of groundwater seeps and springs along the shore of the Columbia River opposite the 1301-N and 1325-N LWDF. The volume of water flowing from the springs has decreased in recent years because the water table in the 100 N Area has lowered with decreased wastewater discharge. The volume and chemistry of spring discharge also depends on the stage of the Columbia River. When the river stage is high, river water flows into the river bank. When the river stage drops, the springs discharge is similar to river water in composition for a time. Gradually the discharge becomes more "groundwater like" as it continues to flow. Spring discharge is also influenced by changes in waste discharge in the 100 N Area. Many springs that were active when large volumes of effluent were being discharged have decrease in volume or dried up altogether (Hartman and Lindsey 1993).

Dirkes (1992) compiled an annotated bibliography of studies that involved sampling Columbia River sediments, springs, or dose rates. Few of the studies compiled contain data specific to the 100 N Area. Routine sampling of the N Springs has been conducted in support of a National Pollutant Discharge Elimination System (NPDES) permit and DOE Order 5400.1 (to monitor radiological releases) (Rokkan 1988, Perkins 1989). Another sampling project was conducted along the river at the 100 Area in 1991 (DOE-RL 1992a, Peterson and Johnson 1992). These reports incorporated the results of previous investigations (Buske and Josephson 1988, McCormack and Carlile 1984, and Dirkes 1990).

Routine sampling of N Springs for the NPDES permit include three components: (1) seep spots; (2) seep wells; and (3) well N-8T. Seep spots are areas where water flows out of the river bank. Samplers sometimes dig out an area near seep spots to collect a sample. Many of the seep spots have dried up in recent years probably due to the stopping of wastewater discharges at 1301-N and 1325-N LWDF. Access is also limited to times when the river stage is low. There are 13 seep wells in the 100 N Area. These are very shallow wells in the river bank. Well N-8T is approximately 50 ft (15 m) from the Columbia River. It is screened between 20 to 30 ft (6 to 9 m) in depth, approximately 5 ft (1.5 m) below the average water table. The well is sampled weekly with a composite sampler. It is used to represent the quality of groundwater flowing out to the river from the N Springs for the NPDES permit. Concentrations of radionuclides from N-8T are slightly higher than at N Springs for most constituents, so the well provides a conservative estimate of radiological releases to the river (Perkins 1989).

2.1.7.3 Ringold Confined Aquifers. The existence of the Ringold confined aquifer system beneath the 100 N Area is inferred on the basis of geologic interpretation and limited borehole data from the surrounding area. Lithologic and stratigraphic data suggest that a system of confined aquifers and aquitards underlies the unconfined aquifer. The members of this aquifer system are listed below, shallowest to deepest (see Figure 2-2):

- Continuous interbedded clay, silt, and sand, approximately 200 ft (60 m) thick--this interval corresponds to the paleosol/overbank interval between units E and B. It is believed to be an aquitard, forming the base of the unconfined aquifer; however thin sand layers are present within the unit, as observed at well 199-N-80. Fluvial sand unit C is also present in this interval. It is thin and silty and probably is not a significant aquifer.

- Silty to clayey sand, approximately 80 to 100 ft (24 to 30 m) thick--this interval corresponds to unit B and may act as an aquifer.

- Laminated deposits of clay and silt, approximately 130 ft (39 m) thick--this interval corresponds to the lower mud unit. These sediments probably have very low permeability and are thought to act as an aquitard.

- Gravel (indurated), approximately 20 ft (6 m) thick--this interval corresponds to unit A, and lies over the Columbia River Basalt. It may act as an aquifer.

Well 199-N-80 was installed in 1992. It penetrates 16 ft (4.8 m) of clay and is completed in a 5 ft (1.5 m) thick layer of sand within a thick paleosol/overbank interval. The sand layer may act as a thin, confined aquifer. The borehole reached another clay unit beneath the sand. Well 199-N-8P was installed in 1966 and is completed within the paleosol/overbank interval (Hartman and Lindsey 1993).

There are recent data on vertical gradients between the uppermost aquifer and deeper units in the 100 N Area from well 199-N-80. The well is not located immediately adjacent to a shallow well, but it is near to and cross-gradient from well 199-N-75. The wells are located near the river. Since this is an area of groundwater discharge most of the year, one would expect to find an upward gradient in the upper aquifer system. However, there seems to be a downward gradient near these wells through most of the year (Hartman and Lindsey 1993).

There appears to be an upward gradient immediately adjacent to the river. Two wells, 199-N-8S and 199-N-8P, are located approximately 10 ft (3 m) apart. Well 199-N-8S is completed approximately 15 ft (4.5 m) below the average water table. Well 199-N-8P is completed in the paleosol/overbank deposit. Water levels in the deeper well are commonly 0.3 to 0.7 m (1 to 2 ft) higher than in the unconfined aquifer, indicating an upward gradient (Hartman and Lindsey 1993).

2.1.7 Biological Resources

Biological resources that are likely to be present at the ERA site have been divided into the following categories: vegetation, wildlife, threatened and endangered species, and sensitive or critical habitats. Each of these is discussed below.

2.1.7.1 Vegetation. The Hanford Site has been botanically characterized as shrub-steppe (Daubenmire 1970). The characteristic plant communities present in the 100 Area are cheatgrass-tumble mustard, sagebrush/cheatgrass or Sandberg's bluegrass, sagebrush-bitterbrush/cheatgrass, and willow-riparian vegetation near the Columbia River shoreline (Cushing 1991). Cheatgrass is prevalent in the 100 Area because of the extensive perturbation of the soils in the area.

Plants likely to be present in the 100 Area include gray rabbit brush *(Chrysothamnus nauseosus)*, cheatgrass *(Bromus tectorum)*, tumbleweed *(Salsola kali)*, yarrow *(Achillea millefolium)*, yellow salsify *(Tragopogon dubius)*, false yarrow *(Chaenactis douglasii)*, and tumble mustard *(Sisymbrium altissimum)* (Cushing 1991, DOE-RL 1991b).

2.1.7.2 Wildlife. Of the approximately 39 species of mammals that have been recorded at the Hanford Site, most are small and nocturnal. The Great Basin pocket mouse *(Perognathus parvus)* is the most common. Muskrats *(Ondatra zibethicus)* and porcupines *(Erithizon dorsatum)* have been observed along the shorelines of streams, ponds, and ditches; beavers

(Castor canadensis) occupy the sloughs along the Columbia River (Cushing 1991). Mule deer *(Odocoileus hemionus)* and raccoons *(Procyon lotor)* are also found or are likely to exist along the Columbia River.

Approximately 187 species of birds have been observed on the Hanford Site (Cushing 1991). The horned lark *(Eremophila alpestris)* and western meadowlark *(Sturnella neglecta)* are the most abundant nesting birds in the shrub-steppe vegetation type. Chinese ring-necked pheasants *(Phasianus colchicus)* and California quail *(Callipepla californicus)* are likely to be found near the Columbia River (Cushing 1991). The Columbia River provides a major nesting area for migrant waterfowl, such as ducks and geese. The most important resident waterfowl is the Canada goose *(Branta canadensis moffitti)*, which rests on the islands of the river. The Hanford Site is located in the Pacific Flyway for migrating bird species; in addition, a major sandhill crane flyway passes over the site (Cushing 1991).

Twelve species of reptiles and amphibians are known to occur on the Hanford Site (Cushing 1991). The side-blotched lizard *(Uta stansburiana)* is the most abundant reptile found at the site. Toads (family: *Bufonidae*) and frogs (family: *Ranidae*) are found along the Columbia River (DOE-RL 1991b).

Of the 44 species of fish that have been identified in the Hanford Reach of the Columbia River, four species use the river as a migration route to and from upstream spawning areas: the chinook salmon *(Oncorhyncus tshawytscha)*, sockeye salmon *(oncorhyncus nerka)*, coho salmon *(Oncorhyncus kisutch)*, and steelhead trout *(Oncorhyncus mykiss)*. A fifth anadromous species, the shad *(Alosa sapidissima)*, may also use the Hanford Reach to spawn (Cushing 1991).

2.1.7.3 Threatened and Endangered Species. Four species of plants that are listed by the federal government as candidate threatened or endangered species and by the State of Washington as either threatened or endangered could be present in the 100 Area:

- Persistentsepal yellowcress (*Rorippa columbiae*): endangered (state), candidate (federal)
- Northern Wormwood (*Artemisia campestris* ssp. *borealis* var. *wormskioldii*): endangered (State), candidate (federal)
- Columbia milk-vetch (*Astragalus columbianus*): threatened (state), candidate (federal)
- Hoover's desert parsley (*Lomatium tuberosum*): threatened (state), candidate (federal).

To date, none of these species has been reported as occurring in the 100 N Area (Cushing 1991, Sackschewsky 1992, and DOE-RL 1992b).

There are several species of birds that are listed by either the federal government or the state of Washington as threatened or endangered that could occur as migrants within the 100 Area:

- Aleutian Canada goose *(Branta canadensis leucopareia)*: endangered (federal and state)
- Peregrine falcon *(Falco peregrinus)*: endangered (federal and state)
- Bald eagle *(Haliaeetus leucocephalus)*: threatened (federal and state)
- White pelican *(Pelecanus erythrorhychos)*: endangered (state)
- Sandhill crane *(Grus canadensis)*: threatened (state)
- Ferruginous hawk *(Buteo regalis)*: threatened (state).

None of these species is known to nest or roost in the 100 N Area (Cushing, 1991). However, bald eagle roosting locations exist at the 100 D and 100 K Areas, and nesting sites have been observed near the 100 F Area (Fitzner and Weiss 1992).

One threatened mammal species, the pygmy rabbit (*Sylvilagus idahoensis*), was once known to exist west of the 200 Area but has not been observed in the 100 Area (DOE-RL 1992b).

2.1.7.4 Sensitive or Critical Habitat. Biological surveys conducted in 1991 and 1992 did not identify any sensitive or critical habitat (habitat that is essential to the support or continuance of a threatened or endangered species) in the area of the proposed ERA (Sackschewsky 1992).

Wetlands habitat exists in the riparian zone that borders the Columbia River. The riparian zone supports stands of willows, grasses, aquatic macrophytes, and other plants. The wetlands along the river are impacted by seasonal and dam-controlled fluctuations in water level.

Some alternatives developed as part of this ERA have assumed placement of the alternative to avoid impact to the 100-year floodplain. The 100-year floodplain was estimated using a discharge for the river of 440,000 ft^3/sec (12,500 m^3/sec). This is the most recent Corps of Engineers estimate for events in the Hanford Reach. This flowrate would result in a zone of flooding to approximately 392 ft (120 m) amsl. The actual placement of the removal system affects both the effectiveness and the cost of the alternative. Factors to be considered include the topography and subsequent surface preparation for system installation, depth to the confining layer, equipment mobility and stability, as low as reasonably achievable (ALARA) practices (area near the river is designated as a radiation zone), legal considerations, and amount of residual contamination in the zone between the removal system and the river. These factors will be more fully analyzed in the design phase of the ERA.

2.1.8 Cultural Resources

The Hanford Site contains numerous, well-preserved archaeological sites representing both the prehistoric and historic periods. The Hanford Reach has been occupied by Native Americans for more than 10,000 years. The river shores contain extensive archaeological deposits (Chatters 1989).

The following Indian tribes have dwelt along or utilized the Hanford Reach for fishing:

- Wanapum and Chamnapum band of the Yakima tribe
- Palus
- Walla Walla
- Umatilla.

Certain landmarks on the Hanford Site, including sites and cemeteries along the Columbia River, are sacred to the Native Americans. Also, certain plant resources that are used in ceremonial activities may be present on the Hanford Site.

Historic resources dating from the 1860's and later at the Hanford Site are represented by remains of homesteads, farm fields, ranches, abandoned U.S. Army installations, gold mine tailings, and the following recorded historic locations (Cushing 1991):

- Allard Pumping Station at Coyote Rapids
- Hanford Irrigation Ditch
- Hanford townsite
- Wahluke Ferry
- White Bluffs townsite
- Richmond Ferry
- Arrowsmith townsite
- East White Bluffs ferry landing
- White Bluffs road
- Old Hanford High School
- Cobblestone Warehouse at Riverland.

The most recent historic sites are the defense reactors and materials processing facilities that have been constructed since World War II.

The 100 N Area is situated on an archaeologically rich segment of the Columbia River shoreline. Within 1.2 mi (2 km) of the area perimeter on the south bank are five recorded sites. Two pithouse village sites and a cemetery comprise the Ryegrass Archaeological District. A fourth site is part of the Hanford Generating Plant Site. All of the sites are either listed in or considered eligible for inclusion in the National Register of Historic Places (Chatters et al. 1990). In addition, two other cairn (or rock pile) sites have been recorded in the upland area east of N Springs. These two sites are considered to be at risk from CERCLA characterization studies (Chatters et al. 1992).

The double-fenced compound of the 100 N Area has been investigated and cleared of cultural resources concerns (Cushing 1991). This means that no known sites of Native American religious or ceremonial significance, or sites included in the National Register of Historic Places, exist within the compound itself. No sites have been recorded along the stretch of riverbank adjacent to the N Springs.

In preparation for this ERA, a cultural resources review was conducted for the N Springs area. The Hanford Cultural Resources Laboratory (HCRL) found no cultural resources in the proposed project area and gave the site a clearance number (Hanford Cultural Resources Clearance [HCRC] #92-100-032).

2.1.9 Visual Resources

The landscape in the vicinity of the Hanford Site is generally flat with little relief. Rattlesnake Mountain, Gable Mountain, and Gable Butte are the highest landforms within the site. The White Bluffs above the northern boundary of the river are a striking feature of the landscape. The Columbia River, flowing adjacent to the 100 N Area, provides a visual source of enjoyment to people. Also, desert flowers blooming in the spring provide an aesthetically pleasing resource (Cushing 1991).

The ERA site is adjacent to the Columbia River. The terrace slopes to the east of the N Springs range up to 460 ft (140 m) high. While the 100 N compound itself might not be considered a pleasing visual resource, the combined aspects of river and plateau downstream from the compound could be considered a source of visual enjoyment.

2.1.10 Land and Water Use

The entire Hanford Site has been designated a National Environmental Research Park (NERP) (Cushing 1991). The 100 Area in general, and particularly the 100 N Area, are not open for use by the public. Land use at the N Springs site along the river is negligible. The majority of any current land use would probably be associated with 100 N Area operations and with environmental monitoring and characterization activities.

The Columbia River is a source of recreational opportunity, especially on the lakes formed by the dams. Because the reach adjacent to the 100 N Area is free-flowing and relatively swift, the recreational use of the river would be limited to adequate power boating, hunting, and fishing, where permitted.

2.2. NATURE AND EXTENT OF CONTAMINATION

A detailed description of the sources, occurrence, and concentration of contaminants at the N Springs ERA site is presented below.

2.2.1 Sources

The two major sources for the contamination released in the N Springs area are the 1301-N and 1325-N LWDF, consisting of cribs and their associated trenches. These cribs are discussed below.

2.2.1.1 1301-N (116-N-1) Liquid Waste Disposal Facility. The 1301-N crib and trench were used between 1964 and 1985 for disposal of liquids from the operation of the 100 N Reactor. The facility made use of the natural filtration and adsorptive properties of the soil to remove the radioactive constituents from the discharged water. The crib is 290 ft (88 m) long, 125 ft (38 m) wide, and approximately 12 ft (3.7 m) deep. The walls of the crib are sloped and covered with soil and gravel. A 3-ft (1-m) layer of boulders was placed in the crib. The zig-zag shaped extension trench extends for 1,600 ft (490 m) and is 50 ft (15 m) wide and 12 ft (3.7 m) deep. Precast concrete panels were placed over the crib and trench to minimize wildlife access and airborne contamination (DOE-RL 1992b).

The liquid wastes disposed to the 1301-N crib and trench were generated from the reactor coolant system, spent fuel storage basin, periphery coolant systems, laboratories, and radioactive drain systems in the reactor facility. The average flow rate to the facility was 2,100 gal/min (7,900 L/min) during reactor operations (DOE-RL 1992b).

The cumulative inventory (accounting for decay as of January 1988) of selected radionuclides disposed to the crib and trench is presented in Table 2-1. Table 2-1 also lists the dangerous wastes disposed to the facility. Tritium and strontium-90 discharges to the 1301-N LWDF through 1990 are listed on Table 2-2. Tritium concentrations in the groundwater are discussed in Section 2.2.3.

The 1301-N crib and trench is currently classified as a Resource Conservation and Recovery Act (RCRA) interim status dangerous waste disposal facility. The DOE prepared a draft closure and post-closure plan (WHC 1987a) for submittal to the Washington State Department of Ecology (Ecology). A new closure and post-closure plan is to be submitted in May 1994, in accordance with milestone M-20-31 of the Tri-Party Agreement (Ecology et al. 1990).

The EPA issued a NPDES permit for the 1301-N facility. The permit requires routine monitoring of discharges to the Columbia River by way of N Springs. The monitoring results are discussed in Section 2.2.4.

2.2.1.2 1325-N (116-N-3) Liquid Waste Disposal Facility. The 1325-N LWDF was constructed as a replacement for the 1301-N LWDF and first received liquid wastes from N Reactor in 1983. Between 1983 and September 1985, both facilities received N Reactor wastes. In September 1985, all flow was diverted to the 1325-N facility. The crib is 250 ft (76 m) long, 240 ft (73 m) wide, and provides 60,000 ft^2 (5,600 m^2) of percolation area. A 3,000 ft (910 m) extension trench was constructed to provide additional operating capacity. The trench is 55 ft (17 m) wide and 7 ft (2 m) deep and is covered by precast concrete panels to prevent access by wildlife (DOE-RL 1992b).

The liquid wastes disposed to the 1325-N crib and trench were the same as those disposed to 1301-N. The average flow rate to the 1325-N facility was 450 gal/min (1,700 L/min) (Connelly et al. 1991).

The cumulative inventory disposed to the 1325-N facility, accounting for decay through September 1985, is listed on Table 2-3. This table also lists an estimate of dangerous wastes disposed to the facility. Tritium and strontium-90 discharges to the 1325-N LWDF through 1990 are listed on Table 2-2. Major discharges were discontinued to this facility in January 1987 when the N Reactor was placed on standby. Small discharges continued until 1991. The crib and trench are not currently receiving any liquid wastes; no discharges are expected in the future. When operations at the N Reactor were discontinued, the 1325 LWDF was put in a standby condition to be used for reactor shutdown operations. However, the facility has subsequently been removed from service and will not be used for reactor shutdown.

The 1325-N LWDF is a RCRA interim status waste disposal facility. As with the 1301-N LWDF, a closure and post-closure plan was prepared by DOE (WHC 1987b) and submitted to Ecology. A new closure and post-closure plan is to be submitted in May 1994, according to the Tri-Party Agreement Milestone M-20-31 (Ecology et al. 1990).

2.2.2 Soil Contaminants

Soil contamination resulted from N Reactor liquids being disposed to the 1301-N and 1325-N LWDF. As the liquids traveled through the vadose zone, radioactive contaminants sorbed onto the soils beneath the LWDF. Retention of radionuclides in the soils is highly variable, ranging from nearly complete retention for cesium-137 to no retention for tritium. Strontium-90 retention is intermediate between these two.

Robertson et al. (1984) conducted a study to determine the migration of radionuclides from the 1301-N LWDF to the N Springs. In this study, wells 199-N-9, 199-N-12, and 199-N-13 were installed to the water table, north of the 1301-N LWDF at distances of approximately 100, 150, and 240 ft (30, 46, and 73 m). Drill cuttings were collected and analyzed for radionuclides. In addition, gamma ray logging tools were run in the wells. Results of the study showed that very low concentrations of radionuclides, such as cobalt-60, ruthenium-106, antimony-125, and cesium-137, were present in well N-9 above the water table. The concentrations increased markedly at the water table. Wells 199-N-12 and 199-N-13 had lower concentrations in the unsaturated zone, but also had higher concentrations at the water table. This study indicates that extensive lateral migration of radionuclides from the LWDF within the vadose zone did not occur during the liquid disposal period. This study, which also addresses the selective removal of radionuclides in the soil column, concludes that the cationic and particulate species are retained in the soil column and the anionic and nonionic species are transported more freely to and within the groundwater. While this study did not address strontium-90 specifically, the results should also be indicative of strontium-90 concentrations in the area. With the cessation of liquid disposal, it is estimated that very high concentrations of radionuclides remain in the soil column between the surface and the groundwater. These contaminants are sorbed onto the soil and the only transport medium for these contaminants is the small amount of precipitation recharge which is occurring from 0.4 to 4 in/yr (1 to 10 cm/yr) (Gee 1987)

Sediment samples were collected for chemical and radiological analysis during drilling of 4 wells in 1992 (Hartman 1993, WHC 1993). Three wells are near the 1301-N LWDF (199-N-75, 199-N-76, and 199-N-80); one is near the 1324-NA percolation pond (199-N-77). Metals concentrations were in the normal range for the Hanford Site. No significant concentrations of organic compounds were identified, except some vegetation-derived material in the upper vadose zone. There is evidence of radionuclide contamination in the vadose zone near the 1301-N LWDF. Cobalt-60 and strontium-90 were detected in the sediments between 50 and 75 ft (15 and 23 m) in depth, an interval that straddles the current water table (Hartman and Lindsey 1993).

A spectral gamma ray borehole log was run in a number of wells and vadose borings in 1992 and 1993 (Price 1993a, 1993b). The logs were run through the permanent casing from surface to total depth (e.g., below the water table). In wells near the 1301-N LWDF (199-N-75, 199-N-76, and 199-N-80), cobalt-60 was detected between approximately 50 to 85 ft (15 to 26 m) depth. The levels of cobalt-60 were similar to those detected by laboratory analyses (Hartman and Lindsey 1993). In wells near the 1325-N LWDF (199-N-27, 199-N-28, 199-N-29, 199-N-39, 199-N-44, and 199-N-70), cobalt-60 was detected between 50 and 90 ft (15 to 27 m). No significant cesium-137, europium-152, or europium-154 were detected. A log of well 199-N-56, upgradient of the 1301-N LWDF, detected no cobalt-60 or other man-made gamma-emitting radionuclides.

The vadose zone in the 100 N Area is contaminated with radionuclides including cobalt-60 and strontium-90 near the 1301-N and 1325-N LWDF, and with petroleum products from underground tanks and pipes near the N Reactor building. Vadose zone studies include field screening and laboratory analyses of samples collected during drilling, and borehole geophysical logging.

2.2.3 Groundwater Contaminants

Groundwater contamination within the N Springs area is primarily the result of liquid waste disposal to the 1301-N and 1325-N LWDF. Neither LWDF is in use any longer; discharges to 1301-N and 1325-N were halted in 1985 and 1991 respectively. As was stated in Section 2.2.1, many of the radionuclides disposed to these facilities have remained adsorbed to the soils and are found only in low concentrations in the groundwater. An example of this is cesium-137, where a combined inventory of 2,650 Ci (decayed to 1985) have been disposed to the two LWDF and the maximum concentration in groundwater (6.68 pCi/l, well 199-N-8S) is significantly below the DOE release limit of 120 pCi/l. Concentrations of radionuclide in the groundwater are also affected by radioactive decay. Radioactive decay halflives for tritium and strontium-90 are 12.3 and 28.1 years respectively.

Representative groundwater analyses are listed in Table 2-4. Samples from these wells were collected during December 1991 and January 1992 as a part of the 1301-N and 1325-N RCRA groundwater monitoring programs.

The 1301-N and 1325-N LWDF are currently under RCRA indicator evaluation monitoring (detection monitoring) programs (Hartman 1993). Results from these monitoring programs indicate that no hazardous chemical constituents are present in the groundwater. Radionuclides, primarily tritium and strontium-90, are present in the groundwater at significant concentrations. Lesser amounts of other radionuclides are also present, but are below regulatory and DOE release limits. Concentration maps for tritium and strontium-90 are presented on Figures 2-6 through 2-9. Figures 2-6 and 2-7 are based on groundwater sampling conducted in February 1990. Figures 2-8 and 2-9 are based on sampling conducted in February 1993. Comparisons of Figures 2-6 and 2-8 indicate that strontium-90 concentrations have declined (between February 1990 and February/March 1993) near the 1325-N LWDF and have remained steady in the groundwater beneath the 1301-N LWDF. Exceptions to this are wells N-3 and N-14 where increases in strontium-90 are noted. Two new wells, N-75 and N-76 were installed in 1992 between the 1301-N LWDF and the Columbia River to supplement the RCRA groundwater monitoring program. It should be noted that there is approximately one order of magnitude difference in concentrations between these two wells. Both wells have been sampled three times and results are consistent. The reason for this is unknown but may be related to localized differences in the adsorptive and desorptive characteristics of the soils in the area. Tritium values for these wells do not show this large difference (Figure 2-9). The declining strontium-90 concentrations in the vicinity of the 1325-N LWDF may be due to the flushing of the saturated soils with noncontaminated groundwater, an overall lower inventory of strontium-90 in the soils, and, to a lesser extent, radioactive decay.

Hartman and Lindsey (1993) report that strontium-90 contamination in groundwater appears to be limited to the top of the unconfined aquifer. Wells screened at the water table (e.g., well N-67) have orders of magnitude more strontium-90 than adjacent wells with screens set only 20 to 30 ft (6 to 9 m) deeper (e.g., well N-69 has no detectable strontium-90). This relationship is not present for tritium however. This suggests that strontium-90 may have sorbed to the sediments near the water table as the contaminated waste water moved downward under the gradient imposed by 1301-N and 1325-N groundwater mounds. Strontium-90 is not transported further down in the unconfined aquifer due to sorption to the sediments (Hartman and Lindsey 1993).

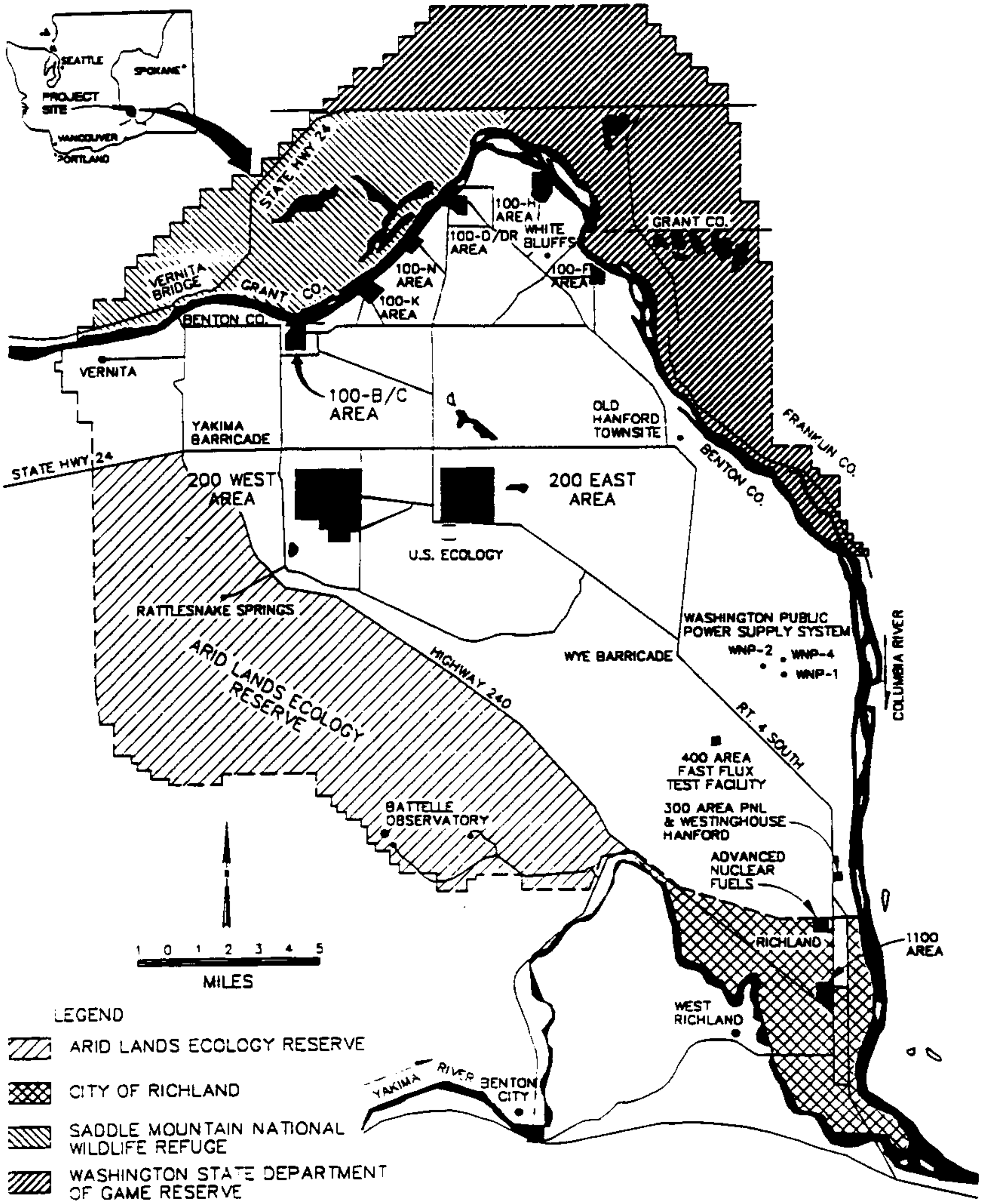
Figures 2-7 and 2-9 show that tritium concentrations overall have declined in the vicinity of the 1325-N LWDF and have remained steady near the 1301-N LWDF. An exception to this is at wells N-14 and N-41 where tritium concentrations have increased and at well N-3 where the concentration declined. Tritium is a nonretarded radionuclide and travels at the same rate as the groundwater. The groundwater flow direction is northerly except near the river as shown on Figures 2-4 and 2-5.

A sulfate plume is present along the western edge of the area. This plume is the result of discharge to the 1324-NA percolation pond. Sulfate is a nonregulated constituent. Hartman and Lindsey (1993) discuss the source and occurance of the sulfate plume in the 100 N Area. Based on the sulfate plume map, contained in Hartman and Lindsey (1993), the plume intersects the southwestern extent of the strontium-90 plume in the N Springs ERA site.

Diesel fuel and other petroleum products have been present on top of the water table beneath the 100 N Area since 1966 (Hartman and Lindsey 1993). The concentration appears to be fairly limited in extent. Wells surrounding the spill have been sampled and reported annually (e.g., Perkins 1992). The leaks and spills occurred near the 100 N Reactor building.

Water samples are collected annually from wells placed in adjacent springs and seeps which discharge to the river. Average results of these analyses for the period from 1985 to 1991 are shown on Figure 2-10. This figure illustrates that generally strontium-90 concentrations are declining with time. Exceptions are at well N-8T and seep wells 3 and 4 which have maintained a more constant concentration. The most recent spring data available (PNL 1993) reports a strontium-90 concentration of approximately 11,000 pCi/L. This is approximately 1.5 times higher than that measured during the previous six years. This may indicate that strontium-90 concentrations are increasing at the springs. It should be noted that this is a different well being sampled than was used for previous sampling efforts. Differences may be the result of different well completions and localized efforts or maybe a true increase in concentrations.

Figure 2-1 Hanford Site



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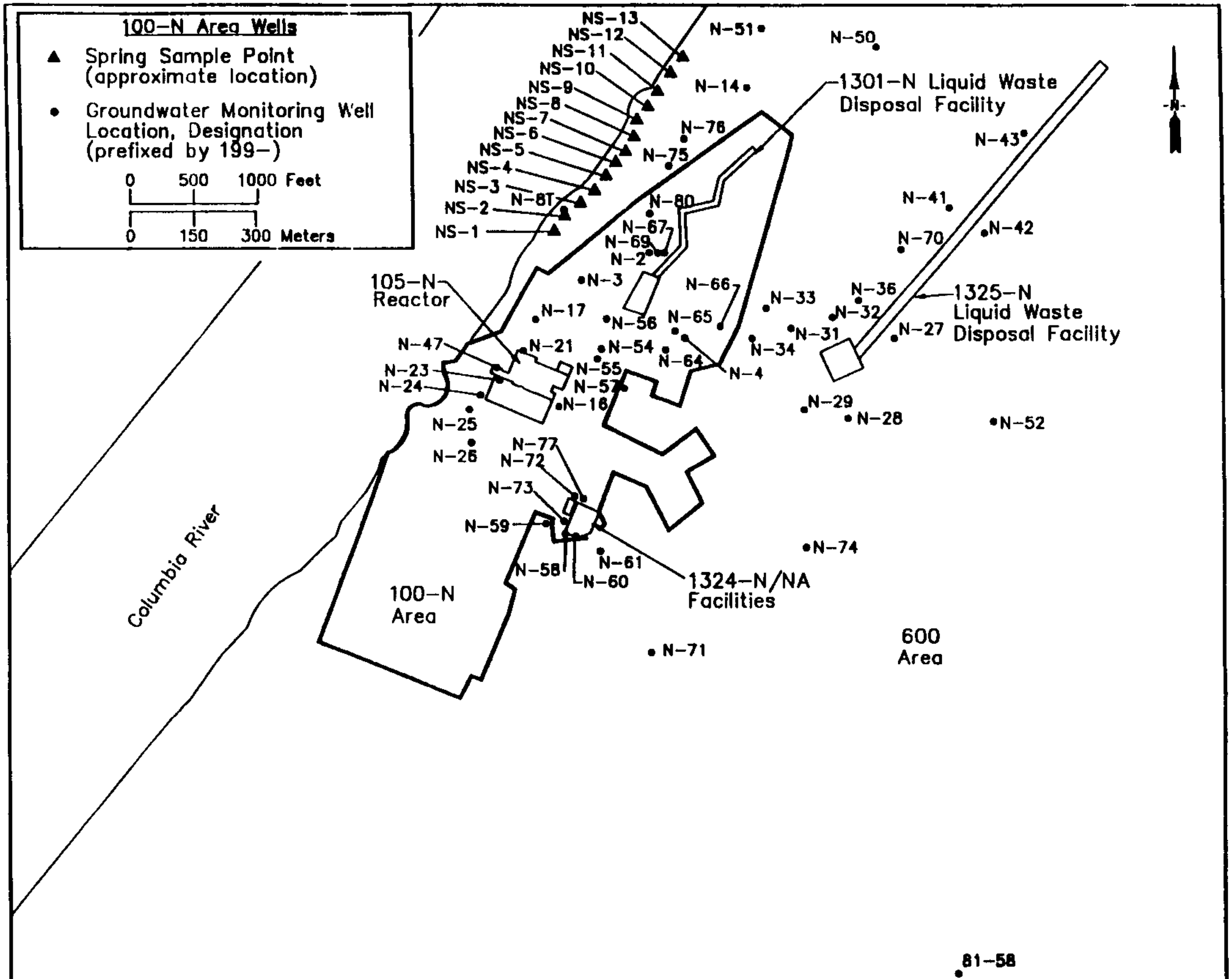

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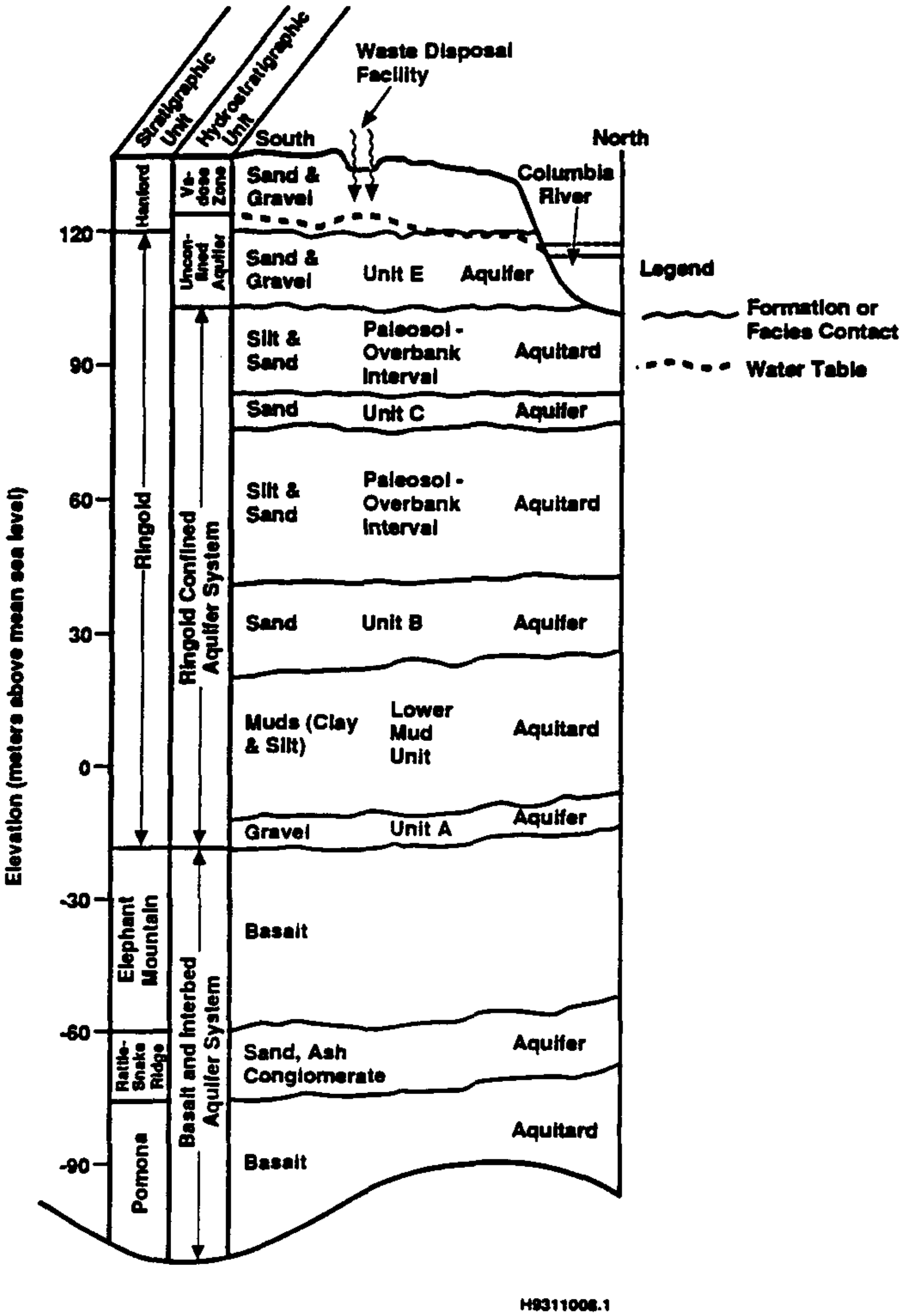
Figure 2-2 N Springs ERA Site Location

Figure 2-3 Conceptual Geologic and Hydrogeologic Column



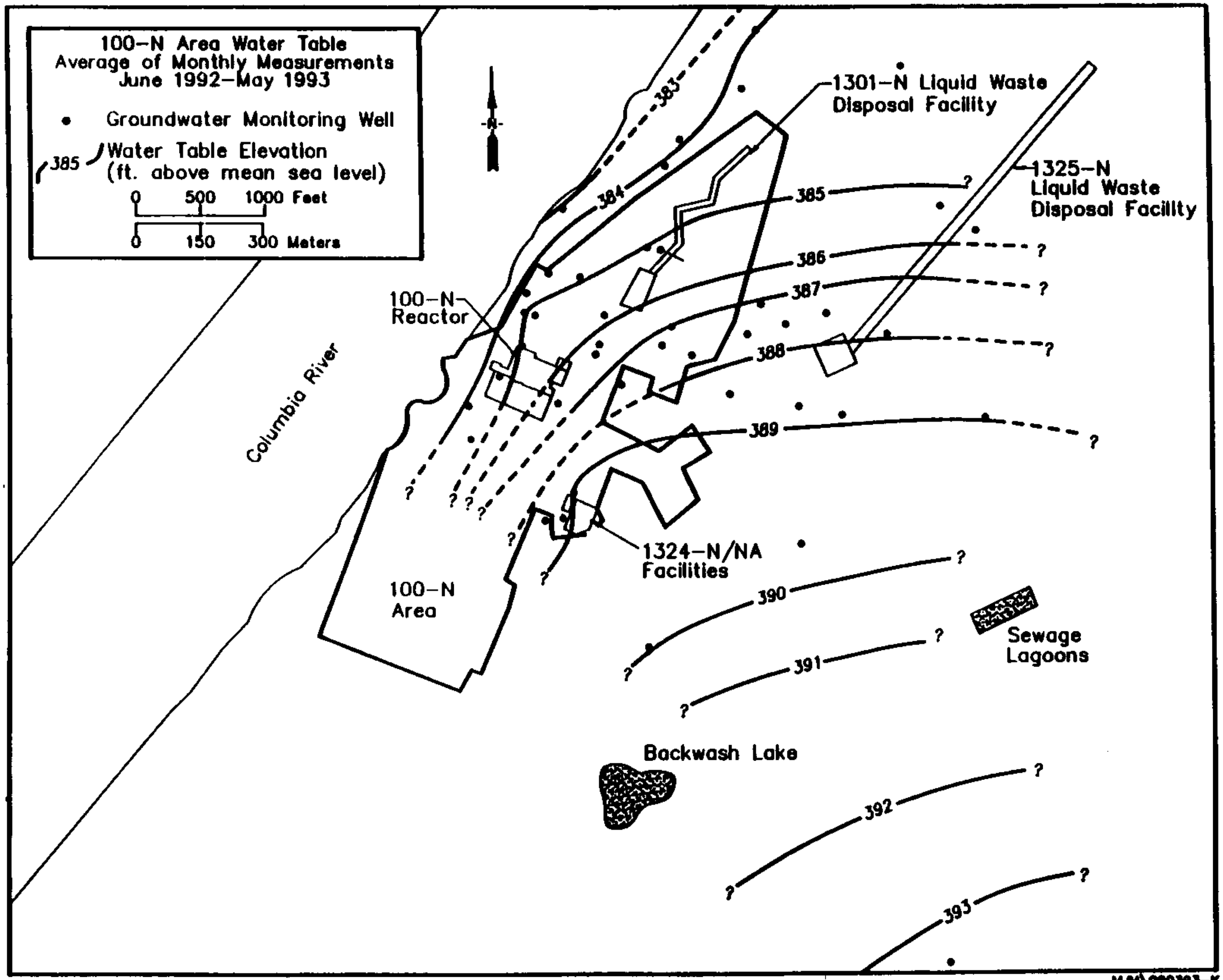


Figure 2-4 100 N Area Water Table - Average Monthly Water Levels June 1992 to May 1993

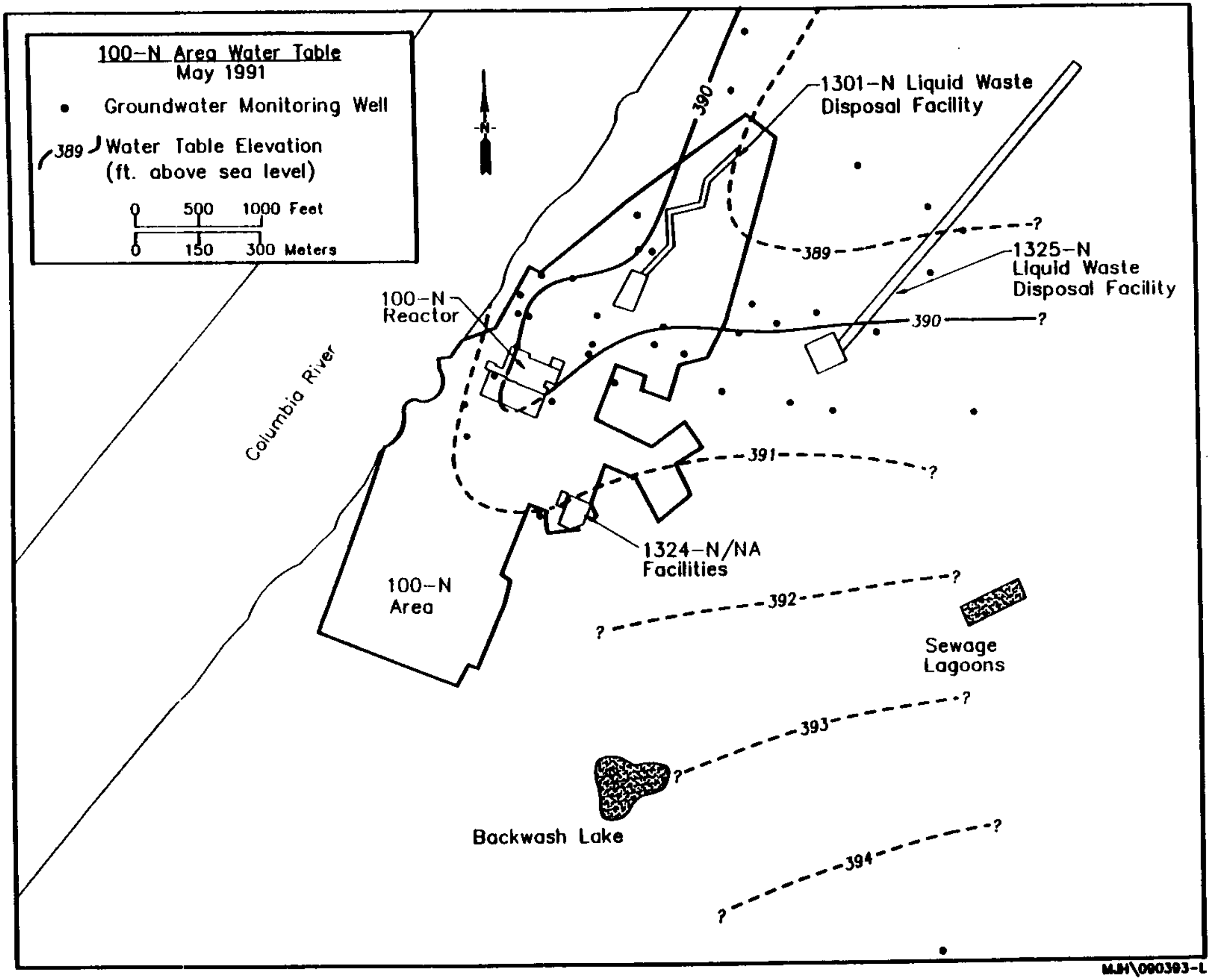


Figure 2-5 100 N Area Water Table - May 1991

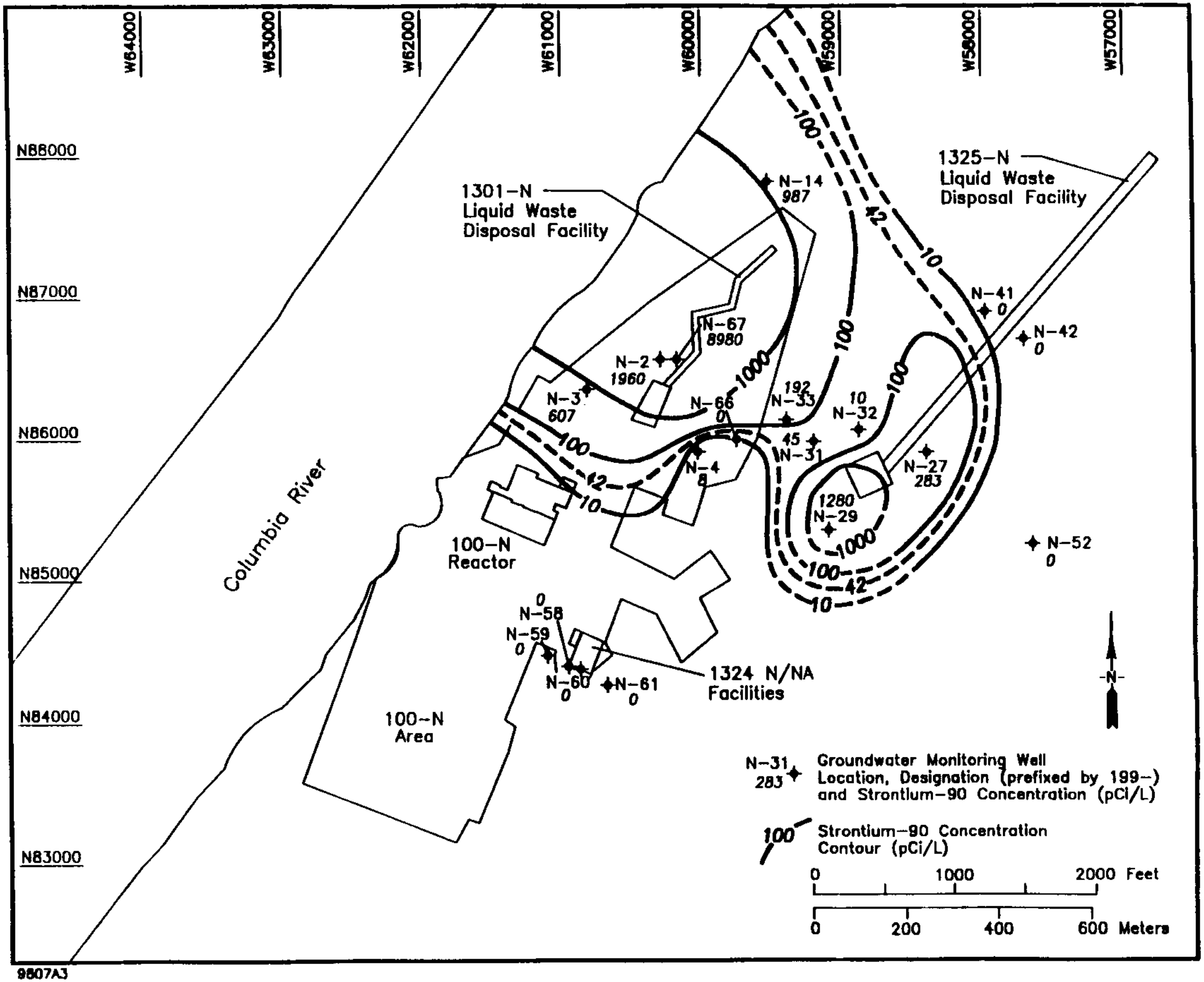
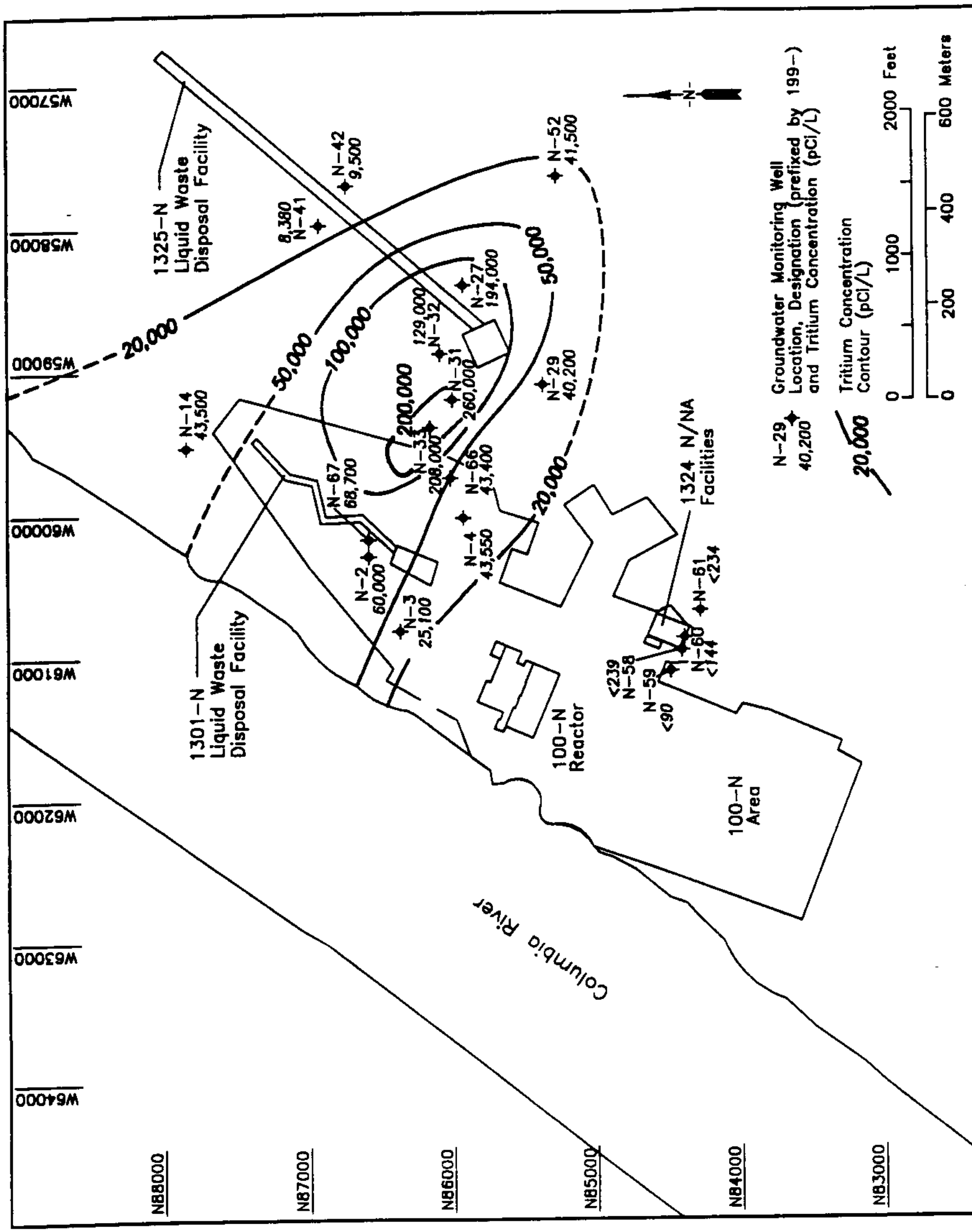


Figure 2-6 Strontium-90 Activity in 100 N Area Groundwater During February 1990

Figure 2-7 Tritium Activity in 100 N Area Groundwater During February 1990



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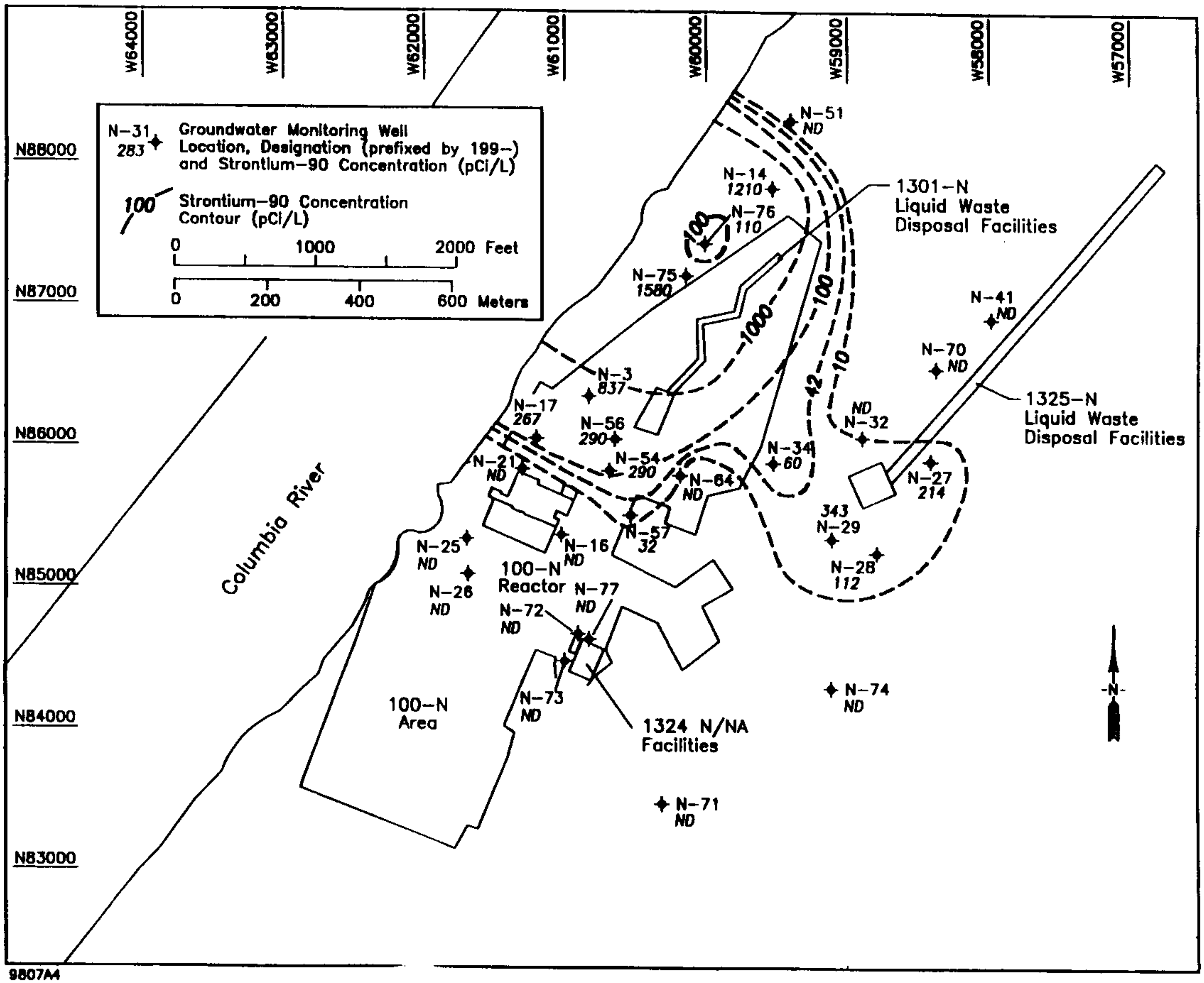

Figure 2-8 Strontium-90 Activity in the 100 N Area Groundwater During February and March 1993

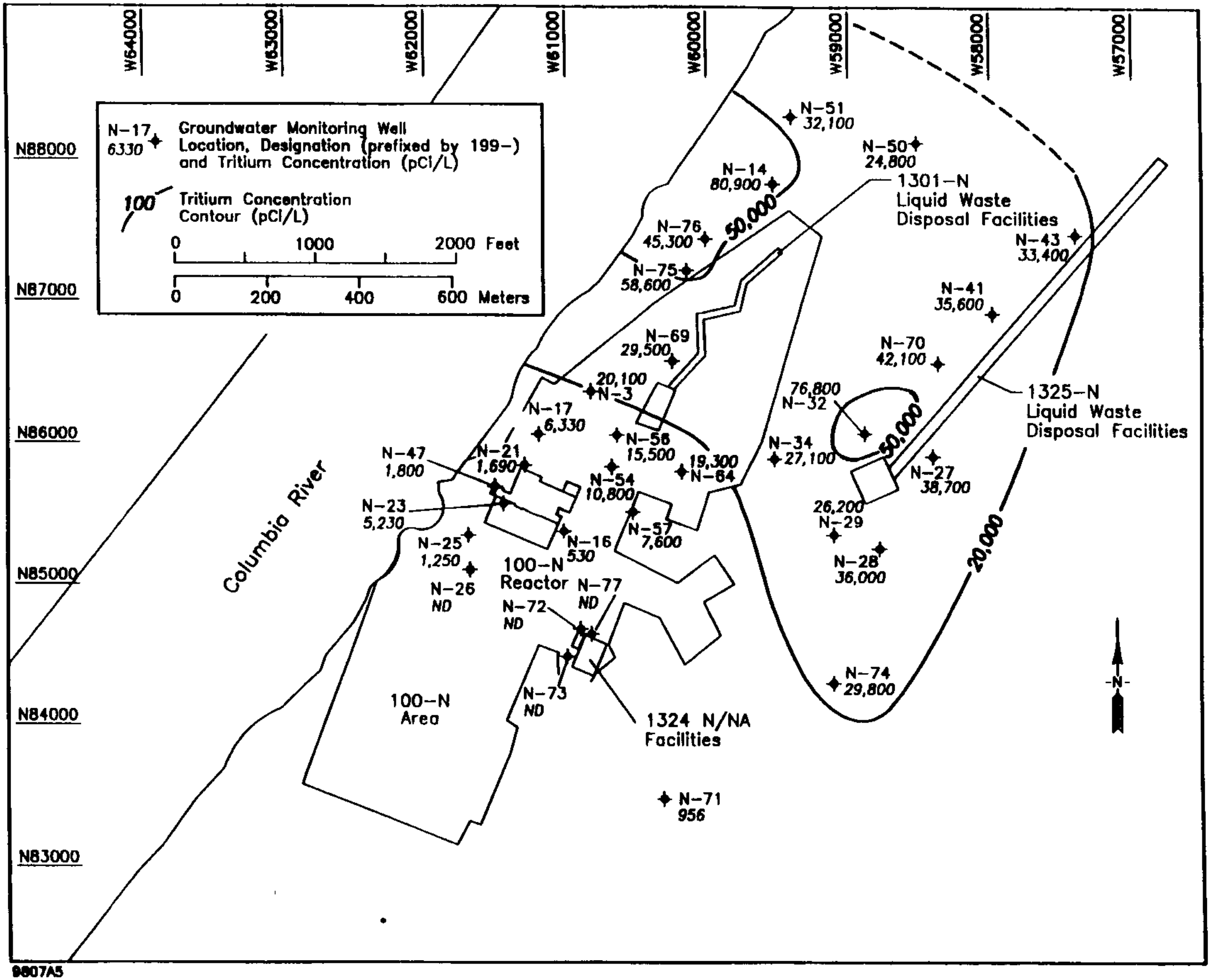

Figure 2-9 Tritium Activity in the 100 N Area Groundwater During February and March 1993

Figure 2-10 Average Strontium-90 Concentrations in the N Springs from 1985 to 1991

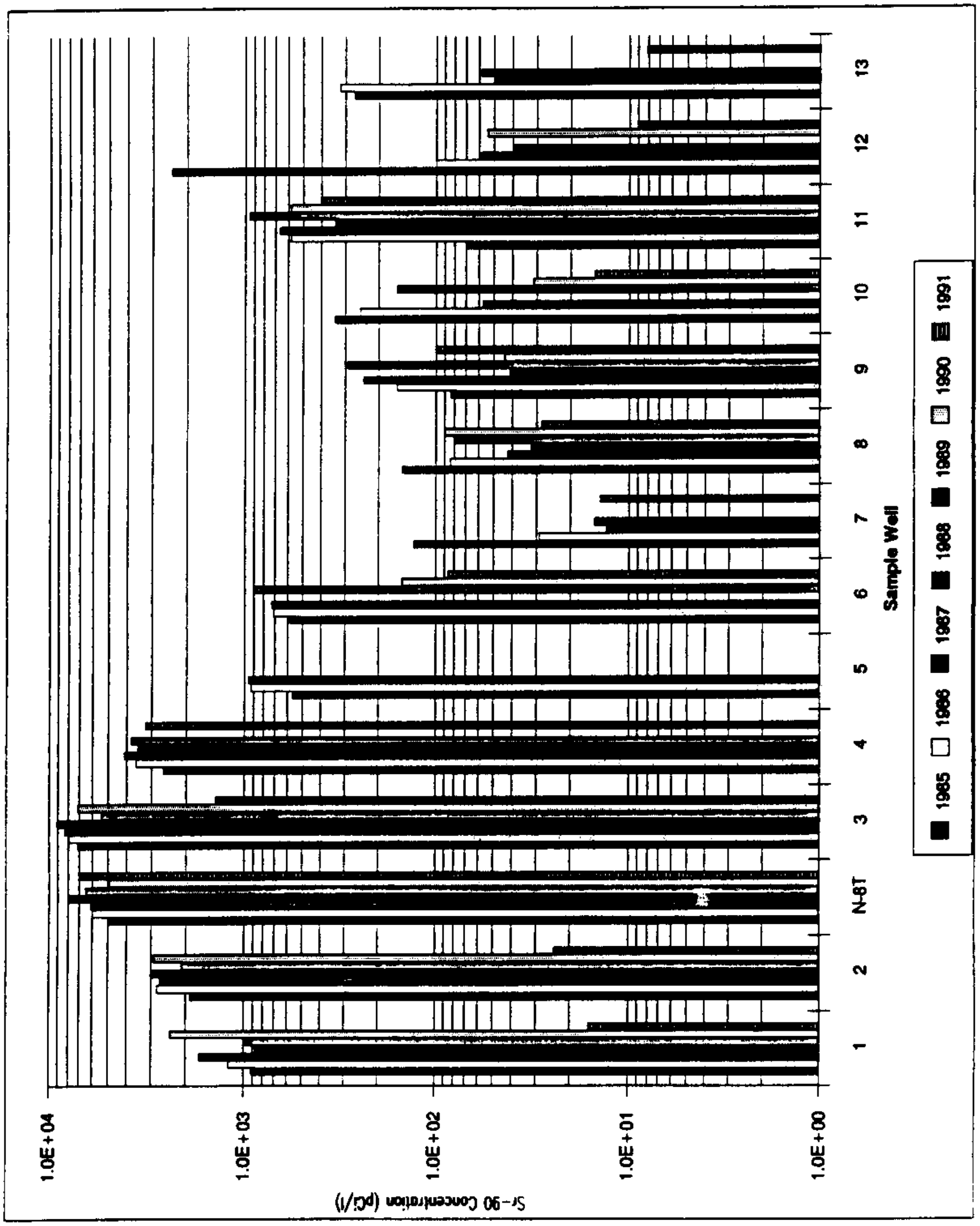

Table 2-1 Radionuclides/Chemical Wastes Disposed to 1301-N Liquid Waste Disposal Facility

Radionuclide	Cumulative Inventory[a] (Ci)
Tritium	3,000
Cobalt-60	3,800
Strontium-90	1,800
Ruthenium-106	120
Cesium-134	51
Cesium-137	2,300
Plutonium-239	18
Chemical Waste	**Disposal Rate (lb/yr)**
Hydrazine Test Solution	6,100
Ammonia Test Solution	6,100
Chloride Test Solution	7,800
Fluoride Test Solution	3,900
Lead-Acetate Battery Fluid	630[b]
Nickel-Cadmium Battery Fluid	270[b]
Hydrazine (Injection System)	350

[a] Accounting for decay to September 1985

[b] Actual amount is not available, but amount shown is possible because of common floor drains.

Sources: DOE-RL 1991b

Table 2-2 Water Flow Rates and Strontium-90 Discharges to 1301-N and 1325-N Liquid Waste Disposal Facilities

Year	Water Flow to 1301-N LWDF (liters/day)	Water Flow to 1325-N LWDF (liters/day)	Average Sr-90 Concentration in Discharges (pCi/liter)	Annual Sr-90 Discharge (Ci/year)	Annual Sr-90 Discharge Accounting for Decay (Ci/year)[2]	Annual Tritium Discharge (Ci/year)	Annual H-3 Discharge Accounting for Decay (Ci/year)[2]
1964[1]	9,462,500	0	20,000	69	35	288	60
1965[1]	9,462,500	0	20,000	69	36	288	63
1966[1]	9,462,500	0	20,000	69	37	288	67
1967[1]	9,462,500	0	20,000	69	38	288	71
1968[1]	9,462,500	0	20,000	69	39	288	75
1969[1]	9,462,500	0	20,000	69	40	288	79
1970[1]	9,462,500	0	20,000	69	41	288	84
1971[1]	9,462,500	0	20,000	69	42	288	88
1972[1]	9,462,500	0	20,000	69	43	288	94
1973	8,702,000	0	4,700	15	9	480	165
1974	9,500,000	0	18,100	63	41	190	69
1975	9,500,000	0	26,800	93	62	130	50
1976	9,900,000	0	30,400	110	75	350	142
1977	14,500,500	0	22,700	120	84	430	185
1978	12,500,000	0	26,300	120	85	330	150
1979	13,500,000	0	26,400	130	95	200	96
1980	12,500,000	0	35,000	160	119	88	45
1981	10,500,000	0	21,900	84	64	82	44
1982	10,500,000	0	36,500	140	110	360	205
1983	6,942,000	1,960,000	43,500	141	114	180	109
1984	8,100,000	1,900,000	84,800	310	255	140	89
1985	7,200,000	2,800,000	65,700	240	202	270	182
1986	0	7,250,000	13,600	36	31	220	157
1987	0	2,100,000	19,600	15	13	98	74
1988	0	1,660,000	24,700	15	14	64	51
1989	0	1,660,000	46,000	28	26	74	63
1990	0	548,000	69,000	14	13	38	34
Total	9,954,864	2,484,750	29,470	2,454	1,760	6,316	2,591

Source: Adapted from Connelly et al. 1991 and WHC 1991. Values for 1989 from Rokkan 1990, values for 1990 from Manley and Diediker 1992.

1 No reliable data for average flow rates and average concentrations of effluents. Rough estimates based on discharge volumes from 1973 to 1976 were used. Data for 1973 through 1990 are from yearly effluent release reports.

2 Decay was accounted for through 1992 using the equation:
Conc. = C exp (-0.693*T/t1/2)
where C = initial activity (Ci), T = number of years since discharge, exp = exponential function
t1/2 = Sr-90 half life = 28.6 yrs, Tritium = 12.33 yrs.

Table 2-3 Radionuclides and Chemical Wastes Disposed to 1325-N Liquid Waste Disposal Facility

Radionuclide	Cumulative Inventory[a] (Ci)
Tritium	95
Cobalt-60	1,300
Strontium-90	200
Ruthenium-106	66
Cesium-134	14
Cesium-137	350
Plutonium-239	2.6
Chemical Waste	**Disposal Rate (lb/yr)**
Hydrazine Test Solution	6,100
Ammonia Test Solution	6,100
Chloride Test Solution	7,800
Fluoride Test Solution	3,900
Lead-Acetate Battery Fluid	120[b]
Nickel-Cadmium Battery Fluid	80[b]
Hydrazine (Injection System)	10

[a] Accounting for decay to September 1985

[b] Actual amount is not available, but amount shown is possible because of common floor drains.

Sources: DOE-RL 1991b

Table 2-4 Groundwater Quality in the Vicinity of the N Springs ERA Site (Page 1 of 3)

Constituent	Units	Well 199-N-2		Well 199-N-3	
		Result	Error[1]	Result	Error[1]
Ammonium ion	ppb	40 U		100 U	
Antimony	ppb	200 U			
Antimony, filtered	ppb	200 U		200 U	
Arsenic	ppb	5 U,H		5 U,H	
Arsenic, filtered	ppb	5 U,H		5 U,H	
Barium	ppb	29			
Barium, filtered	ppb	20 U		47	
Beryllium	ppb	3 U			
Beryllium, filtered	ppb	3 U		3 U	
Bromide	ppb	500 U		500 U	
Cadmium	ppb	10 U			
Cadmium, filtered	ppb	10 U		10 U	
Calcium	ppb	27000			
Calcium, filtered	ppb	24000		53000	
Chloride	ppb	1500		5500	
Chromium	ppb	20 U			
Chromium, filtered	ppb	20 U		20 U	
Cobalt	ppb	20 U			
Cobalt, filtered	ppb	20 U		20 U	
Coliform bacteria	MPN	1 U		1 U	
Copper	ppb	20 U			
Copper, filtered	ppb	20 U		20 U	
Fluoride	ppb	100		600	
Iron	ppb	1400			
Iron, filtered	ppb	20 U		24	
Lead (graphite furnace)	ppb	5 U,H		5.7 H	

Table 2-4 Groundwater Quality in the Vicinity of the N Springs ERA Site (Page 2 of 3)

Constituent	Units	Well 199-N-2		Well 199-N-3	
		Result	Error[1]	Result	Error[1]
Lead, filtered	ppb	5 U,H		5 U,H	
Magnesium	ppb	5100			
Magnesium, filtered	ppb	4400		8900	
Manganese	ppb	43			
Manganese, filtered	ppb	10 U		10 U	
Mercury	ppb	0.2 U		0.2 U	
Mercury, filtered	ppb	0.2 U		0.2 U	
Nickel	ppb	30 U			
Nickel, filtered	ppb	30 U		30 U	
Nitrate	ppb	3400		15500	
Nitrite	ppb	200 U		200 U	
pH, Field Measurement		7.92		7.54	
Phosphate	ppb	400 U		400 U	
Potassium	ppb	2200			
Potassium, filtered	ppb	1300		2700	
Selenium	ppb	10 U		10 U	
Selenium, filtered	ppb	10 U		10 U	
Silver	ppb	20 U			
Silver, filtered	ppb	20 U		20 U	
Sodium	ppb	2700			
Sodium, filtered	ppb	2500		9600	
Specific conductance	μmho/cm	167		365	
Sulfate	ppb	14000		35000	
Temperature, field	DEG-C	21.8		20.9	
Tin	ppb	100 U			
Tin, filtered	ppb	100 U		100 U	

Table 2-4 Groundwater Quality in the Vicinity of the N Springs ERA Site
(Page 3 of 3)

Constituent	Units	Well 199-N-2		Well 199-N-3	
		Result	Error[1]	Result	Error[1]
Total organic carbon	ppb	1000 U		2000	
Total Organic Halogen, Low Detection Level	ppb	10 U		10 U	
Turbidity	NTU	2.1		0.6	
Uranium, chemical	μg/L			1.66	0.5692
Vanadium	ppb	30 U			
Vanadium, filtered	ppb	30 U		30 U	
Zinc	ppb	10 U			
Zinc, filtered	ppb	10 U		10 U	
Cobalt-60	pCi/L	12.4	6.304	4.8 U	9.644
Cesium-137	pCi/L	0 U	0.000001	-7.34 U	8.58
Ruthenium-106	pCi/L	-40.7 U	53.06	-22.3 U	61.66
Antimony-125	pCi/L	13.8 U	15.95	4.12 U	17.23
Tritium	pCi/L	30100	2362	21300	1760
Gross beta	pCi/L	637	50.04	1170	97.4
Strontium-90	pCi/L	336	64.42	557	98.07
Radium	pCi/L	0.00867 U	0.08794	0.0131 U	0.1716
Gross alpha	pCi/L	0.202 U	0.5426	0.622 U	0.7956

U Result is less than the contract required quantitation limit (CRQL); reported value is the CRQL. For radionuclides the value is less than the error.
H Recommended holding time was exceeded.
[1] Error refers to the statistical counting error resulting from radiological analyses.

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3.0 REMOVAL ACTION OBJECTIVES DEVELOPMENT

Removal action objectives (RAO) define the "why," "what," and "when" of a removal action. Within the scope of an EE/CA study, the RAO delineate the limits of acceptable technical performance and institutional factors. The RAO are developed by first identifying the chemicals of potential concern (COPC) and ARAR.

3.1 CHEMICALS OF POTENTIAL CONCERN

Strontium-90 is the principal COPC at N Springs. While strontium-90 is the COPC driving this removal action, other constituents in the groundwater must be considered in the evaluation of alternatives. Tritium, for example, is elevated above Safe Drinking Water Act of 1974 maximum contaminant levels (MCL) in the 100 N Area and will be a significant consideration for disposal of treated groundwater. A sulfate plume is located near the strontium-90 plume; any alternative that results in changes to the groundwater flow may cause movement of the sulfate plume. Should the plumes intersect, sulfate must be addressed in the alternative evaluation and design. A similar situation exists with a hydrocarbon plume; alternatives which affect groundwater movement must consider the potential effect of the hydrocarbon on the treatment system. While these additional contaminants may effect design of the alternatives, no contaminants are present which preclude the identified alternatives. Table 2-4 presents recent analysis of the groundwater as sampled from wells 199-N-2 and 199-N-3.

3.2 POTENTIAL APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Section 121(d) of CERCLA, as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), requires that fund-financed, enforcement, and federal facility remedial actions comply with ARAR of federal environmental laws and more stringent, promulgated state environmental or facility siting laws. While these requirements generally apply as a matter of law to remedial actions, ARAR for removal actions should be identified and complied with to the extent practicable.

The CERCLA defines applicable requirements as those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site.

Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site.

In addition to ARAR, CERCLA also provides for the consideration of to-be-considered (TBC) guidance, nonpromulgated advisories or guidance documents issued by federal or state governments that do not have the status of potential ARAR but which may be considered in determining necessary levels of protection of health or the environment.

Applicable or relevant and appropriate requirements may be further subdivided into the following categories:

- *Chemical-specific requirements* - health- or risk-based numerical values or methodologies that, when applied to site-specific conditions, result in the establishment of numerical values. If a chemical has more than one such requirement that is ARAR, compliance should generally be with the most stringent requirement.

- *Location-specific requirements* - restrictions placed on the concentration of hazardous substances or the conduct of activities solely because they are in specific locations, such as wetlands or historic places.

- *Action-specific requirements* - technology- or activity-based requirements or limitations on actions taken with respect to hazardous wastes. These requirements are triggered by the particular remedial activities that are selected to accomplish a remedy.

Potential ARAR identified in the *100 Area Feasibility Study, Phases 1 and 2* (DOE-RL 1993) were reviewed and refined for appropriateness to the N Springs ERA. Potential chemical-specific ARAR and TBC identified for the N Springs ERA are listed in Tables 3-1 through 3-3. Potential action- and location-specific ARAR and TBC are presented in Tables 3-4 through 3-9.

3.3 REMOVAL ACTION OBJECTIVES

The primary objective of the N Springs ERA is to eliminate or significantly reduce the flux of strontium-90 to the Columbia River through the N Springs. For purposes of this evaluation, significant reduction was considered to be at least 50% of the strontium-90 concentrations greater than 1,000 pCi/L. Currently, strontium-90 is being discharged to the river via the N Springs at concentrations that exceed the drinking water MCL of 8 pCi/L for strontium-90. A secondary objective of the ERA is to implement a removal action that will be compatible with future remedial actions planned for the operable unit and will contribute to the efficient performance of the final remedial action to be taken.

For those alternatives that include extraction of contaminated groundwater, the objective is to treat the water to MCL prior to disposal. Tritium is the exception because treatment for tritium removal is currently unavailable. Disposal of tritiated water will require waivers of applicable ARAR.

Table 3-1 Potential Federal Chemical-Specific ARAR (Page 1 of 2)

Description	Citation	Requirements	Remarks
Clean Air Act, as amended	42 U.S.C. 7401 et seq.	A comprehensive environmental law designed to regulate any activities that affect air quality, providing the national framework for controlling air pollution.	
National Primary and Secondary Ambient Air Quality Standards	40 CFR Part 50	Sets National Ambient Air Quality Standards for ambient pollutants which are regulated within a region.	
Air Standards for Particulates	40 CFR §50.6	Prohibits average concentrations of particulate emissions in excess of 50 micrograms/m^3 annually or 150 micrograms/m^3 per 24-hour period.	A potential for particulate emissions exists during excavation for vertical barrier installation.
National Emissions Standards for Hazardous Air Pollutants (NESHAP)	40 CFR Part 61	Establishes numerical standards for hazardous air pollutants.	
Radionuclide Emissions from DOE Facilities (except Airborne Radon-222)	40 CFR §61.92	Prohibits emissions of radionuclides to the ambient air exceeding an effective dose equivalent of 10 mrem per year.	Applicable to removal technologies where air emissions may occur.
Federal Water Pollution Control Act, as amended by the Clean Water Act of 1977	33 U.S.C. 1251 et seq.	Creates the basic national framework for water pollution control and water quality management.	
National Pollutant Discharge Elimination System (NPDES)	40 CFR Part 122	Establishes permitting requirements, technology-based limitations and standards, control of toxic pollutants, and monitoring of effluents to assure permit conditions and limits are not exceeded.	Permit may not be required for CERCLA actions; however, substantive requirements must be met.
Permit Conditions	40 CFR §122.41-122.50	Establishes conditions that apply to NPDES permits including effluent limitations and monitoring requirements.	Applicable to direct discharges of wastewaters to waters of the U.S. Treatment of process waters that will be discharged to waters of the U.S. will be required to meet all applicable effluent limitations, quality standards, and toxic pollutant discharge standards as determined by the state, and/or federal discharge permitting authority.

Table 3-1 Potential Federal Chemical-Specific ARAR (Page 2 of 2)

Description	Citation	Requirements	Remarks
Safe Drinking Water Act	42 U.S.C. 300f et seq.	Creates a comprehensive national framework to ensure the quality and safety of drinking water.	
National Primary Drinking Water Regulations	40 CFR Part 141	Establishes maximum contaminant levels (MCL) and maximum contaminant level goals (MCLG) for organic, inorganic, and radioactive constituents. The MCL for Sr-90 is 8 pCi/L. The average annual concentration of beta particle and photon radioactivity from manmade radionuclides in drinking water shall not produce an annual dose equivalent to total body or any internal organ in excess of 4 mrem/year.	Pertains to public drinking water supplies. Chemicals of potential concern are being discharged to the river which serves as a drinking water supply downstream.
National Secondary Drinking Water Regulations	40 CFR Part 143	Controls contaminants in drinking water that primarily affect the aesthetic qualities relating to the public acceptance of drinking water.	Although federal secondary drinking water standards are not enforceable, they are potential ARARs under the Washington State Model Toxics Control Act when more stringent than other standards. See state ARARs.

Table 3-2 Potential State Chemical-Specific ARAR

Description	Citation	Requirements	Remarks
Nuclear Energy and Radiation	RCW 70.98		
Radiation Protection - Air Emissions	WAC 246-247	Requires that emissions of radionuclides to the air shall not cause a dose equivalent of more than 25 mrem/year to the whole body or 75 mrem/year to a critical organ of any member of the public.	
Model Toxics Control Act (MTCA)	70.105D RCW	Requires remedial actions to attain a degree of cleanup protective of human health and the environment.	
Cleanup Regulations	WAC 173-340	Establishes cleanup levels and prescribes methods to calculate cleanup levels for groundwater.	
Groundwater Cleanup Standards	WAC 173-340-720	Requires that where the groundwater is a potential source of drinking water, cleanup levels under Method B must be at least as stringent as concentrations established under applicable state and federal laws, including the following: (A) Maximum contaminant levels established under the Safe Drinking Water Act and published in 40 CFR 141, as amended; (B) Maximum contaminant level goals for noncarcinogens established under the Safe Drinking Water Act and published in 40 CFR 141, as amended; (C) Secondary maximum contaminant levels established under the Safe Drinking Water Act and published in 40 CFR 143, as amended; and (D) Maximum contaminant levels established by the state board of health and published in Chapter 248-54 WAC, as amended.	Federal maximum contaminant level goals for drinking water (40 CFR Part 141) and federal secondary drinking water regulation standards (40 CFR Part 143) are potential ARARs under MTCA when they are more stringent than other standards.

Table 3-3 Chemical-Specific TBC

Description	Citation	Requirements	Remarks
Safe Drinking Water Act	42 U.S.C. 300f et seq.		
National Primary Drinking Water Regulations; Radionuclides - Proposed Rules	FR Vol. 56, No. 138, July 18, 1991	Provides numerical standards for radionuclides corresponding to 4 mrem/yr dose through drinking water as follows (pCi/L): Tritium 69,040 Strontium-90 42	When promulgated, these proposed rules will replace sections in 40 CFR 141 and 142
U.S. Department of Energy Orders			
Radiation Protection of the Public and the Environment	DOE 5400.5	Establishes radiation protection standards for the public and environment.	
Radiation Dose Limit (All Pathways)	DOE 5400.5, Chapter II, Section 1a	The exposure of the public to radiation sources as a consequence of all routine DOE activities shall not cause, in a year, an effective dose equivalent greater than 100 mrem from all exposure pathways, except under specified circumstances.	Pertinent if remedial activities are "routine DOE activities."
Radiation Dose Limit (Drinking Water Pathway)	DOE 5400.5, Chapter II, Section 1d	Provides a level of protection for persons consuming water from a public drinking water supply operated by DOE so that persons consuming water from the supply shall not receive an effective dose equivalent greater than 4 mrem per year. Combined radium-226 and radium-228 shall not exceed 5 x 10^{-9} µCi/mL and gross alpha activity (including radium-226 but excluding radon and uranium) shall not exceed 1.5 x 10^{-8} µCi/mL.	Pertinent if radionuclides may be released during remediation.

Table 3-4 Potential Federal Action-Specific ARAR

Description	Citation	Requirements	Remarks
Federal Water Pollution Control Act (FWPCA), as amended by the Clean Water Act of 1977 (CWA)	33 U.S.C. 1251 et seq.	Creates the basic national framework for water pollution control and water quality management in the United States.	
The National Pollutant Discharge Elimination System (NPDES)	40 CFR Part 122	Part 122 covers establishing technology-based limitations and standards, control of toxic pollutants, and monitoring of effluent to assure limits are not exceeded.	Applicable to river discharge option for treated groundwater disposal; also applies to storm water runoff associated with industrial activities.
NPDES Criteria and Standards	40 CFR §125.104	Best management practices program shall be developed in accordance with good engineering practice.	
Safe Drinking Water Act (SDWA), as amended			
Underground Injection Control (UIC) Program	40 CFR Part 144	Identifies the minimum requirements for UIC programs.	Applicable for the reinjection option of treated groundwater disposal.
Criteria and Standards for the Underground Injection Control Program	40 CFR Part 146	Establishes siting, construction, operating, monitoring, and closure requirements for all classes of injection wells.	Applicable for the reinjection option of treated groundwater disposal.
Resource Conservation and Recovery Act (RCRA)			
Identification and Listing of Hazardous Waste	40 CFR Part 261	Identifies by both listing and characterization, those solid wastes subject to regulation as hazardous wastes under Parts 261-265, 268 and 270.	Applicable if remediation techniques result in generation of hazardous wastes.
Standards Applicable to Generators of Hazardous Waste	40 CFR Part 262	Describes regulatory requirements imposed on generator of hazardous wastes who treat, store, or dispose of the waste on-site.	Applicable if remediation techniques results in generations of hazardous wastes.

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Table 3-5 Potential State Action-Specific ARAR (Page 1 of 2)

Description	Citation	Requirements	Remarks
Department of Ecology	43.21A RCW	Vests the Washington Department of Ecology with the authority to undertake the state air regulation and management program.	
Air Pollution Regulations	WAC 173-400	Establishes requirements for the control and/or prevention of the emission of air contaminants.	Applicable if emission sources are created during remedial action.
Standards for Maximum Emissions	WAC 173-400-040	Requires best available control technology be used to control fugitive emissions of dust from materials handling, construction, demolition, or any other activities that are sources of fugitive emissions. Restricts emitted particulates from being deposited beyond Hanford. Requires control of odors emitted from the source. Prohibits masking or concealing prohibited emissions. Requires measures to prevent fugitive dust from becoming airborne.	Applicable to dust emissions from cutting of concrete and metal and vehicular traffic during remediation.
Emission Limits for Radionuclides	WAC 173-480	Controls air emissions of radionuclides from specific sources.	Applicable to remedial activities that result in air emissions.
New and Modified Emission Units	WAC 173-480-060	Requires the best available radionuclide control technology be utilized in planning construction, installation, or establishing a new emission unit.	Applicable to remedial actions that result in air emissions.
Dangerous Waste Regulations	WAC 173-303	Establishes the design, operation and montitoring requirements for management of hazardous wastes.	Includes requirements for generators of dangerous waste. Dangerous waste includes the full universe of wastes regulated by WAC 173-303 including extremely hazardous waste.

Table 3-5 Potential State Action-Specific ARAR (Page 2 of 2)

Description	Citation	Requirements	Remarks
Model Toxics Control Act	70.105D RCW	Authorizes the state to investigate releases of hazardous substances, conduct remedial actions, carry out state programs authorized by federal cleanup laws, and to take other actions.	
Hazardous Waste Cleanup Regulations	WAC 173-340	Addresses releases of hazardous substances caused by past activities, and potential and ongoing releases from current activities.	Applicable to facilities where hazardous substances have been released, or there is a threatened release that may pose a threat to human health or the environment.
Selection of Cleanup Actions	WAC 173-340-360	Establishes cleanup requirements to include in cleanup plans. Identifies technologies to be considered for remediation of hazardous substances.	
Cleanup Actions	WAC 173-340-400	Ensures that the cleanup action is designed, constructed, and operated in accordance with the cleanup plan and other specified requirements.	
Institutional Controls	WAC 173-340-440	Requires physical measures such as fences and signs to limit interference with cleanup, and legal and administrative mechanisms to enforce them.	
Water Pollution Control Act	90.48 RCW	Prohibits discharge of polluting matter in waters.	
Underground Injection Control Program	WAC 173-218	Establishes permitting requirements for injection of fluids through wells. Prohibits injection of any dangerous or radioactive waste fluids. Prohibits injection of industrial or commercial waste fluids beneath the lowermost formation containing, within 1/4 mile of the well, an underground source of drinking water.	Federal Criteria and Standards for the Underground Injection Control Program (40 CFR 146) are reserved at this time.
State Waste Discharge Permit Program	WAC 173-216		
Permit terms and conditions	WAC 173-216-110	Requires all known, available, and reasonable methods of prevention, control, and treatment be used as a condition of the permit to discharge to the waters of the state.	While a permit is not required under CERCLA actions, the substantive requirements of that permit must be met.
Water Well Construction Act	18.104 RCW		
Standards for Construction and Maintenance of Wells	WAC 173-160	Establishes minimum standards for design, construction, capping, and sealing of all wells. Sets additional requirements including disinfection of equipment, abandonment of wells, and quality of drilling water.	Applicable if water supply wells, monitoring wells, or other wells are utilized during remediation.

Table 3-6 Action-Specific TBC

Description	Citation	Requirements	Remarks
Residual Radioactive Material as Surface Contamination	U.S. NRC Regulatory Guide 1.86	Sets contamination guidelines for release of equipment and building components for unrestricted use, and if buildings are demolished, shall not be exceeded for contamination in the ground.	
U.S. Department of Energy Orders			
Radiation Protection of the Public and the Environment	DOE 5400.5	Establishes standards and requirements for operations of DOE and DOE contractors respecting protection of the public and the environment against undue risk of radiation.	
Discharge of Treatment System Effluent	DOE 5400.xy	Treatment systems shall be designed to allow operators to detect and quantify unplanned releases of radionuclides, consistent with the potential for off-property impact.	Required of all DOE-controlled facilities where radionuclides might be released as a consequence of an unplanned event.
Radiation Protection for Occupational Workers	DOE 5480.11 Section 9a	Establishes radiation protection standards and program requirements to protect workers from ionizing radiation.	
Radioactive Waste Management	DOE 5820.2A Chapters III and IV	Establishes policies and guidelines by which DOE manages radioactive waste, waste by-products, and radioactive contaminated surplus facilities. Disposal shall be on the site at which it was generated, if practical, or at another DOE facility. DOE waste containing byproduct material shall be stored, stabilized in place, and/or disposed of consistent with the requirements of the residual radioactive material guidelines contained in 40 CFR 192.	

Table 3-7 Potential Federal Location-Specific ARAR

Description	Citation	Requirements	Remarks
Archaeological and Historical Preservation Act of 1974	16 U.S.C. 469	Requires action to recover and preserve artifacts in areas where activity may cause irreparable harm, loss, or destruction of significant artifacts.	Applicable because of the presence of significant scientific, prehistorical, historical, or archeological data in the N Area.
Endangered Species Act of 1973	16 U.S.C. 1531 et seq.	Prohibits federal agencies from jeopardizing threatened or endangered species or adversely modifying habitats essential to their survival.	
Fish and Wildlife Services List of Endangered and Threatened Wildlife and Plants	50 CFR Parts 17, 222, 225, 226, 227, 402, 424	Requires identification of activities that may affect listed species. Actions must not threaten the continued existence of a listed species or destroy critical habitat.	Requires consultation with the Fish and Wildlife Service to determine if threatened or endangered species could be impacted by activity.
Historic Sites, Buildings, and Antiquities Act	16 U.S.C. 461	Establishes requirements for preservation of historic sites, buildings, or objects of national significance. Undesirable impacts to such resources must be mitigated.	Applicable because of the presence of
National Historic Preservation Act of 1966, as amended.	16 U.S.C. 470 et seq.	Prohibits impacts on cultural resources. Where impacts are unavoidable, requires impact mitigation through design and data recovery.	Applicable to properties listed in the National Register of Historic Places, or eligible for such listing.
Wild and Scenic Rivers Act	16 U.S.C. 1271	Prohibits federal agencies from recommending authorization of any water resource project that would have a direct and adverse effect on the values for which a river was designated as a wild and scenic river or included as a study area.	The Hanford Reach of the Columbia River is under study for inclusion as a wild and scenic river.

Table 3-8 Potential State Location-Specific ARAR

Description	Citation	Requirements	Remarks
Habitat Buffer Zone for Bald Eagle Rules	RCW 77.12.655		
Bald Eagle Protection Rules	WAC 232-12-292	Prescribes action to protect bald eagle habitat, such as nesting or roost sites, through the development of a site management plan.	Applicable if the areas of remedial activities includes bald eagle habitat.
Regulating the Taking or Possessing of Game	RCW 77.12.040		
Endangered, Threatened, or Sensitive Wildlife Species Classification	WAC 232-12-297	Prescribes action to protect wildlife classified as endangered, threatened, or sensitive, through development of a site management plan.	Applicable if wildlife classified as endangered, threatened, or sensitive are present in areas impacted by remedial activities.

Table 3-9 Location-Specific TBC

Description	Citation	Requirements	Remarks
Floodplains/Wetlands Environmental Review	10 CFR Part 1022	Requires federal agencies to avoid, to the extent possible, adverse effects associated with the development of a floodplain or the destruction or loss of wetlands.	Pertinent if remedial activities take place in a floodplain or wetlands.
Protection and Enhancement of the Cultural Environment	Executive Order 11593	Provides direction to federal agencies to preserve, restore, and maintain cultural resources.	Pertains to sites, structures, and objects of historical, archeological, or architectural significance.
Hanford Reach Study Act	PL 100-605	Provides for a comprehensive river conservation study. Prohibits the construction of any dam, channel, or navigation project by a federal agency for 8 years after enactment. New federal and non-federal projects and activities are required, to the extent practicable, to minimize direct and adverse effects on the values for which the river is under study and to utilize existing structures.	This law was enacted November 4, 1988.

4.0 IDENTIFICATION OF REMOVAL ACTION TECHNOLOGIES

The *100 Area Feasibility Study Phases 1 and 2* (DOE-RL 1993) serves as a basis for defining technologies and process options considered for this ERA. Technology types are general groups of operations with common characteristics or results, such as physical treatment. Process options are specific operations within a technology type, such as ion exchange. The process options defined in the feasibility study (FS) for vertical barriers, hydraulic control, and groundwater physical, biological, and chemical treatment technology types are screened for applicability to the circumstances at N Springs. Table 4-1 identifies those technologies and process options relevant to the proposed action at N Springs that were considered in the FS. Some of these technologies are eliminated from further consideration because they do not specifically address the type of contamination at N Springs; that is, they are not applicable. The rationale for the elimination of technologies and process options is indicated in the table. Descriptions of the technologies that are eliminated are given in the FS (DOE-RL 1993). Technologies that are retained for further consideration are briefly described in Section 6.0. Screening of technologies and process options against the removal action screening criteria is documented in Section 5.0.

Table 4-1 Technology Identification (Page 1 of 2)

Technology	Is technology applicable to N Springs?
Vertical Barriers	
Slurry Wall	Yes
Grout Curtain	Yes
Sheet Pilings	Yes
Freeze Wall	Yes
Biological Barriers	No; difficult to maintain stable barrier and potential to mobilize contaminants
Permeable Treatment Beds	Yes
Pump and Treat	
Extraction Wells	Yes
Ion Exchange	Yes
Media Filtration	Yes; consider for water pretreatment to remove suspended solids
Flocculation/Precipitation	Yes
Carbon Adsorption	No; used for VOC
Air Stripping	No; used for VOC
Reverse Osmosis	Yes
Ultrafiltration	No; used for higher molecular weight contaminants
Electrodialysis	No; has not been proven for radionuclides
Dissolved Air Flotation	No; used for removing fine solids with densities close to water
Sedimentation	Yes; consider for pretreatment to remove larger sediment particles in suspension (in conjunction with media filtration)
Steam Stripping	No; used for organics
Forced Evaporation	Yes; as a secondary treatment for treatment of waste liquids to reduce volume
Freeze Crystallization	No; used for heavy metals and partially soluble organics

Table 4-1 Technology Identification (Page 2 of 2)

Technology	Is technology applicable to N Springs?
Supported Liquid Membrane	Yes
Chemical Oxidation	No; used for organics
Wet-Air Oxidation	No; used for organics
Chemical Reduction	No; used for hexavalent chromium
Solidification/Stabilization	Yes; consider as secondary treatment for treatment residues
Hydraulic Control	
Extraction Wells	Yes
Extraction Trenches	Yes
Treated Water Disposal	
Crib Disposal	Yes
River Discharge	Yes
Reinjection	Yes
Passive solar evaporation	Yes
Double Shell Tanks	No; capacity not available; volume increase of high level waste
242-A Evaporator	No; capacity not available
Grout Facility	No; volume exceeds capacity; costs excessive

VOC - volatile organic compound

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5.0 SCREENING OF REMOVAL ACTION TECHNOLOGIES

The screening of removal action technologies and process options is conducted to eliminate technologies and process options that do not meet the ERA screening criteria. The following factors are used for this screening analysis:

- protectiveness
- timeliness
- technical feasibility
- institutional considerations.

The list of technologies and process options that were retained from Section 4.0 for analysis in the screening includes the following:

- Pump and Treat - Extraction
  - extraction wells.

- Pump and Treat - Treatment
  - ion exchange
  - reverse osmosis
  - supported liquid membrane
  - flocculation
  - sedimentation
  - media filtration
  - forced evaporation
  - solidification/Stabilization.

- Pump and Treat- Treated Water Disposal
  - river discharge
  - crib disposal
  - reinjection
  - passive solar evaporator.

- Vertical Barriers
  - slurry wall
  - grout curtain
  - sheet pilings
  - freeze wall
  - permeable treatment beds.

- Hydraulic Control
  - extraction wells
  - extraction trenches.

In addition to these technologies, at the request of DOE's Richland Operations Office (RL), two innovative technologies are considered in screening: strontium biosorption and strontium solvent extraction with ionizable crown ethers. In their comments to the ERA project plan, the U.S. Environmental Protection Agency (EPA) also requested that wetlands bioassimilation be considered.

The screening of technologies and process options listed above is discussed in the following subsections.

5.1 SCREENING CRITERIA

Criteria for screening removal action technologies and process options are derived from the draft EPA guidance document *Draft Engineering Evaluation/Cost Analysis Guidance for Non-Time-Critical Removal Actions* (EPA 1987a). The criteria are described briefly as follows:

- Protectiveness
  - Does the technology protect human health and the environment?
  - Will the technology provide ultimate long-term mitigation of threats to human health and the environment?
  - Are there any potential long-term threats posed by the technology? What is the severity of these threats?

- Timeliness
  - Can approval processes, contracting, mobilization, testing, and storage capacity be obtained on a timely basis?
  - Are site-specific factors conducive to timely implementation?

- Technical feasibility
  - Has the technology been proven in large, field-scale applications?
  - Has the technology been used on similar site conditions, media, and contaminants?

- Institutional considerations
  - Will the public accept the technology?
  - Does the technology require acquisition of permits?
  - Is the technology able to comply with essential chemical and location specific ARAR?
  - Does the technology require the cooperation of other agencies or organizations?

5.2 TECHNOLOGY SCREENING

This section documents the screening process for determining which technologies and process options should be developed into alternatives for detailed analysis. Each subsection provides a brief description of the technology or process option. The rationale for retaining or eliminating technologies and process options, based on evaluation against the screening criteria, is provided in Table 5-1.

5.2.1 Pump and Treat - Extraction Wells

Groundwater extraction wells are used to withdraw and isolate contaminated groundwater by manipulation of the hydraulic gradient (RAAS 1991). The extraction system may include a single well or multiple wells. The complexity of the design depends on the nature of the transporting medium, the depth of penetration of the contaminants, and the complexity of the geologic stratigraphy. The extraction process is used in conjunction with groundwater treatment and disposal.

5.2.2 Pump and Treat - Treatment Process Options

A wide range of primary and secondary treatment process options is considered for treating extracted contaminated water at the N Springs. Brief descriptions are provided below.

5.2.2.1 Ion Exchange. The ion exchange process adsorbs ionic contaminants in exchange for mobile ions of similar charge that are contained on organic resin beads or on inorganic materials such as zeolites. Both anions and cations, including radionuclides, can be removed from water by use of appropriate ion exchange media. The process involves pumping the contaminated water through vessels containing beds of ion exchange media. Configurations and combinations of ion exchangers containing either cation or anion media, or mixtures of the two, may be specified to operate either in series or parallel based on the volume of contaminated water to be treated. Media are chemically regenerated using concentrated salt or acid solutions that result in substantial volumes of secondary waste requiring treatment, usually by evaporation. Some media, such as synthetic zeolites, are used without regeneration. That is, the spent media are disposed of as solid waste after they become fully loaded with contaminants. The advantage of this type of media is that secondary liquid wastes are not generated.

Ion exchange is commercially available and proven. It is commonly used in DOE facilities and in the nuclear industry for a wide variety of processing and wastewater treatment applications (RAAS 1991).

5.2.2.2 Reverse Osmosis. The reverse osmosis process purifies contaminated water by application of high pressure which forces pure water through a semipermeable membrane but leaves the contaminants in a concentrated waste stream (EPA 1987b). The process is commercially available and highly effective for purifying water containing dissolved ions and radionuclides. However, a chief disadvantage is the generation of a substantial volume of secondary liquid waste that must be volume reduced and solidified prior to disposal.

5.2.2.3 Supported Liquid Membrane. The supported liquid membrane process is a variation of reverse osmosis. A liquid membrane consists of a micro-porous membrane containing an organic carrier held in place by capillary forces. Carriers are used to increase the selectivity of the membrane for specific constituents, potentially reducing the volume of secondary waste generated relative to reverse osmosis. Supported liquid membrane technology is currently in the experimental development phase. No commercial applications are known.

5.2.2.4 Flocculation. Flocculation is a proven physical process where inorganic contaminants are coagulated by the addition of chemicals (Freeman 1989). Flocculation is effective in removing suspended solids and is used in conjunction with sedimentation and/or filtration to remove the particles from water (DOE 1990).

5.2.2.5 Sedimentation. Sedimentation is a proven physical separation process whereby particles entrained in a liquid are separated by induced settling with gravitational or inertial forces (NRC 1981). For N Springs, it would be considered as a pretreatment step for removal of suspended particulates in the raw groundwater. Sedimentation produces a wet sludge as a secondary waste that must be dewatered or solidified and disposed.

5.2.2.6 Media Filtration. Media filtration is a common pretreatment step to remove solids from suspension by using media, such as diatomaceous earth or beds of sand (EPA 1987b). Depending upon particle sizes and quantities to be removed, cartridge-type filters containing fabric bags or porous metallic elements can also be used for filtration. Filtration produces secondary solid waste requiring disposal.

5.2.2.7 Forced Evaporation. Forced evaporation is a proven process for reducing the volume of aqueous wastes. Forced evaporation would be considered for use in reducing the volume of secondary liquid wastes from reverse osmosis or ion exchange treatment. Vaporization of water is induced by raising the temperature of the waste stream mechanically by vapor recompression or in a heated evaporator. Vapor is then separated, condensed, and discharged. The concentrate requires further processing to render it a solid waste. This can be accomplished by drying or solidifying with cement or other solidification materials.

5.2.2.8 Solidification/Stabilization. This process is used to eliminate free liquids and immobilize contaminants so that the waste material can be land-disposed. The waste liquids or wet sludges are mixed with cement, fly ash, polymers or other suitable solidification material. The technology is well developed and commercially practiced for use in radioactive waste disposal. The technology would be considered for use in solidifying secondary wastes from reverse osmosis, ion exchange, filtration, and/or evaporation.

5.2.3 Pump and Treat - Treated Water Disposal Options

No practical treatment process is available for removing tritium from the N Springs groundwater. Thus several disposal options are considered for comparison to river discharge. Each is described briefly below.

5.2.3.1 River Discharge. This option provides a baseline for evaluation. Treated water containing tritium is discharged directly into the river via a pipeline and river outfall.

5.2.3.2 Crib Disposal. Crib disposal is a subsurface water discharge method whereby water is allowed to percolate through the porous soil column into groundwater. The particles of the soil column essentially act as filters by adsorbing contaminants. Two crib disposal options are considered for N Springs: disposal at the N Area and disposal at the 200 Area. Crib disposal at the 200 Area allows sufficient travel time of tritiated water to the river so that the tritium would decay to very low levels by the time it reached the river. However, the chief disadvantage of this option is that a long and costly pipeline would have to be constructed to allow pumping the water to the 200 Area. Crib disposal to the N Area does not allow sufficient travel time for tritium decay. Both options would require a waiver of Tri-Party Agreement Milestone M-17 which requires the cessation of liquid effluent releases.

5.2.3.3 Reinjection. In this option, treated water is reinjected directly into the aquifer using conventional screened injection wells. Injected water would flow through the aquifer and into the river. Water would be injected at a location in the N Area that does not impact contaminated plume movement. The advantage of this option is that clean vadose zone soil is not contaminated with injected water.

5.2.3.4 Passive Solar Evaporation. Passive solar evaporation is a proven technology that uses large shallow surface impoundments or open tanks to evaporate water using solar radiation. The impoundments must be lined to prevent the water from percolating into the soil. Nets or other protection are also required to prevent animal access. The release of tritium to the air is a potential concern with passive evaporation. At present, treatment options for tritium in air are unavailable. Also, capture of emissions from a passive solar evaporator would be impracticable.

5.2.4 Vertical Barriers

Vertical barriers act as an obstruction to the groundwater pathway of contaminant migration. Because the flow of contaminants at N Springs is generally from the 1301-N and 1325-N cribs toward the river, a vertical barrier placed between these contaminant sources and the river may eliminate or substantially restrict the movement of contaminants to the river by leveling the groundwater flow gradient behind the wall. Strontium-90 has a tendency to bind to the soils. This tendency, combined with the decrease in the flow gradient, results in a decrease of strontium-90 movement and thus a reduction in the flux to the river. In addition, some reduction in strontium-90 concentrations occurs as a result of natural radioactive decay. This effect is limited, however, for this ERA because of the assumed timeframe of 10 years. Strontium-90 has a half-life nearly triple the proposed timeframe. A discussion of each type of barrier considered is given in the subsections below.

5.2.4.1 Slurry Wall. A slurry wall is a vertical barrier formed by emplacement of slurry in a vertical trench or boring. Conventional trench excavation uses backhoes or clamshell excavators; the slurry is used to shore the trench as excavation proceeds. New techniques for slurry wall construction have been commercialized whereby walls are built using deep soil mixing. In deep soil mixing, large-diameter augers are used to simultaneously drill, inject slurry, and mix slurry with soil materials. Slurry materials can include soil-bentonite or cement-bentonite mixes (slurry recipe would be determined through field testing). Slurry walls are typically designed for permeabilities of 10^{-7} cm/sec, but performance can be greater or less depending upon the type of slurry used, soil conditions, and placement techniques. The slurry wall technology has been proven on large, field-scale applications under similar circumstances and is commercially available.

5.2.4.2 Grout Curtain. A grout curtain is a vertical barrier used to reduce or contain groundwater flow. Grout curtains are formed by pressure injection of grout through pipes, augers, or beams that are inserted into the ground using a drill rig. The curtain is developed one "post" at a time along the containment boundary. Grout curtains are implementable and effective at waste sites. However, the presence of very coarse-grained and non-uniform materials in the Hanford formation increases the uncertainty in the proper positioning of the grout posts and in the integrity of grout penetration and coverage. The high permeability soils would inhibit the formation of a grout curtain by reducing the ability to control continuity of grout placement.

5.2.4.3 Sheet Pilings. Sheet pilings are vertical barriers constructed of materials such as wood, precast concrete, or steel. The walls, or sheets, are typically assembled at the surface and then driven into the ground a few feet at a time over the entire length of the wall with a vibratory or drop hammer.

Sheet pilings are not feasible at N Springs because of the presence of large boulders and rocky soils that would cause damage or deflection of the walls. This damage or deflection would result in unpredictable wall integrity.

5.2.4.4 Freeze Wall. A freeze wall, or cryogenic wall, is a vertical barrier formed by freezing interstitial water within the soils. The freeze wall is formed by circulating coolant through steel pipes installed in the ground. Pipes are installed using conventional drilling techniques. To facilitate an effective frozen wall, the pipes must be installed on a relatively close spacing (6-7 ft). Freeze walls have been used successfully in special construction applications where temporary groundwater barriers were necessary. However, this technology is considered innovative for use in hazardous waste management as it has not yet been applied in site remediation (Dash 1991, EPA 1990).

The implementability of the freeze wall is very difficult and costly because of the need for a large number of holes. A vendor estimated that approximately 800 holes, 120 ft deep, would be required for a 2800-ft wall at N Springs. Using cable tool or sonic drilling would require over 40 rig-years for installation and would incur costs over $80M. Thus this technology is neither technically feasible nor cost effective for Hanford application.

5.2.4.5 Permeable Treatment Beds. Permeable treatment beds are excavated trenches placed perpendicular to groundwater flow and filled with an appropriate material to treat the plume of contamination as it flows through the material (EPA 1985). Permeable treatment beds are also referred to as permeable barriers (EPA 1990). The technology category is also referred to as in situ sorption (RAAS 1991). Possible treatment materials or adsorbents include activated carbon, agricultural residues, clays, zeolites, glauconitic greensand, and limestone (RAAS 1991). In the case of N Springs, zeolites and glauconitic greensands, which are high surface area cation exchange materials, would probably be the most appropriate materials for removing strontium-90.

The technology is applicable to relatively shallow groundwater tables containing a plume. The application of permeable treatment beds at hazardous waste sites has not been performed (EPA 1985, EPA 1990), although bench- and pilot-scale testing for specific applications have been undertaken (EPA 1990). The DOE Office of Technology Development has proposed that research and development (R&D) programs on permeable barriers be included in the In Situ Remediation Integrated Program (Peterson 1992).

A major drawback in using permeable treatment beds is that the materials may become fully loaded with contaminants and other adsorbed constituents and may lose their adsorption characteristics (RAAS 1991). In addition, permeable barriers may become clogged with precipitates necessitating periodic removal, treatment and/or disposal as hazardous/radioactive waste. Therefore, this technology should be considered only as a temporary containment measure (RAAS 1991).

Because permeable treatment beds have not been proven in hazardous waste field applications, and therefore no performance data exist, the degree of protectiveness and the technical feasibility of this technology at N Springs are uncertain.

5.2.5 Hydraulic Control

5.2.5.1 Extraction Wells. Extraction wells, described in Section 5.2.1, are used for hydraulic control by placement upgradient from the contaminated plume. By pumping groundwater upgradient from the contaminated plume, the natural flow is intercepted so that the gradient in the area of the contamination is lowered and the flow of groundwater towards the river is slowed. This reduction in flow reduces the rate of contaminant transport into the river. The hydraulic control wells are placed sufficiently upgradient from the plume so the contaminated water is outside the radius of influence of the wells. Thus the water pumped by upgradient control wells is not contaminated and can be discharged to the river without treatment.

5.2.5.2 Extraction Trenches. Extraction trenches are sometimes used for hydraulic control instead of a line of extraction wells. The trench, which is constructed with permeable material, provides a subsurface drain by which the flow of groundwater can be intercepted. Pumps are used to remove the groundwater that flows into the trench. Trenches are more beneficial than wells where the groundwater and the contamination are shallow or where the geologic conditions would require a large number of closely spaced wells. Neither is the case for N Springs, because the N Area groundwater is deep and the aquifer is porous so that wells would not be closely spaced.

5.2.6 Miscellaneous Technologies

At the request of DOE-RL, selected innovative technologies were evaluated for their potential application in the N Springs ERA.

5.2.6.1 Strontium Biosorption. Laboratory-scale studies have been performed at Oak Ridge National Laboratory (ORNL) on the adsorption of strontium from wastewater using immobilized microorganisms (Faison et al. 1990, Watson et al. 1990, Watson et al. 1989). The experiments were performed using laboratory glass packed-columns containing microbial cells (bacteria) immobilized on beads of a gelatin matrix. The experiments concluded that microbial cells can adsorb strontium from dilute solutions.

While the laboratory studies performed to date show promise, this innovative technology is in the very early stages of development. The potential advantage of this technology relative to conventional ion exchange media is that the microbial media may be less expensive, more selective for strontium, and have higher loading capacities; however, these advantages have yet to be demonstrated.

Because this technology is not yet sufficiently developed, it cannot be shown to meet the ERA selection criteria of timeliness, protectiveness, and technical feasibility. Therefore, this technology will not be considered further for the N Springs ERA.

5.2.6.2 Solvent Extraction With Ionizable Crown Ethers. Laboratory experiments have been performed by researchers at the University of Idaho on the extraction of strontium-90 and other radionuclides from aqueous phase into chloroform using a new class of selective chelating agents called ionizable crown ethers (Wai and Du 1990, Tang and Wai 1989, Tang and Wai 1988). The published papers discuss results of work aimed at understanding the chemistry of the process and do not delve into applications.

From the information available, it is apparent that the technique is in the very early research stage. Much more research and development remain to demonstrate practical application. Thus, because this technology does not meet the ERA selection criteria, it will not be considered further for N Springs.

5.2.6.3 Wetlands Bioassimilation. Wetlands bioassimilation refers to the utilization of wetlands plants to uptake and accumulate contaminants such as metals and radionuclides contained in wastewater. This innovative technology would be used in combination with groundwater extraction; the water would be pumped from the aquifer and discharged to artificial wetlands onsite in which plants would be grown and harvested. Harvested plants containing metals and radionuclides would then be permanently disposed by compaction and burial as solid waste.

Wetlands have been used for control of urban runoff. There is evidence that some metals are biologically accumulated in plants grown where contaminants exist. However, no performance data exist on effectiveness or secondary effects of this technique. While the concept may have merit, more research is needed before the concept could be considered for hazardous site remediation.

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Table 5-1 Screening of Technologies and Process Options (Page 1 of 3)

Process Option	Technical Feasibility, Timeliness	Technical Feasibility	Protectiveness	Technical Feasibility, Institutional Considerations	Retain Process Option for Detailed Analysis?
	Is Process Option Commercially Available?	Has Process Option Been Used in Similar Circumstances?	Is Process Option Sufficiently Effective?	Is Process Option Implementable?	
Pump and Treat - Extraction					
Extraction Wells	Yes	Yes	Yes	Yes	Yes
Pump and Treat - Treatment					
Ion Exchange	Yes	Yes	Yes	Yes	Yes
Reverse Osmosis	Yes	Yes	Yes	Yes	Yes
Selective Liquid Membrane	No	No	Uncertain	Uncertain	No
Flocculation	Yes	Yes; for pretreatment	Yes; for pretreatment	Yes	Yes[1]
Sedimentation	Yes	Yes	Yes	Yes	Yes[1]
Media Filtration	Yes	Yes; for pretreatment	Yes; for pretreatment	Yes	Yes[1]
Forced Evaporation	Yes	Yes; for secondary waste treatment	Yes; for secondary waste treatment; potential for tritium release to air*	Yes	Yes[2]
Solidification/ Stabilization	Yes	Yes	Yes	Yes	Yes[3]
Pump and Treat - Disposal Options					
Crib Disposal	Yes	Yes	Yes	Yes	Yes
River Discharge	Yes	Yes	Yes	Yes	Yes
Reinjection	Yes	Yes	Yes	Yes	Yes

Table 5-1 Screening of Technologies and Process Options (Page 2 of 3)

Process Option	Technical Feasibility, Timeliness	Technical Feasibility	Protectiveness	Technical Feasibility, Institutional Considerations	Retain Process Option for Detailed Analysis?
	Is Process Option Commercially Available?	Has Process Option Been Used in Similar Circumstances?	Is Process Option Sufficiently Effective?	Is Process Option Implementable?	
Passive Evaporation	Yes	Unknown	Tritium in groundwater would be released to air*; potential leaks to soil; control of animal exposure uncertain	Yes	No
Vertical Barriers					
Slurry Wall	Yes	Yes	Yes	Yes	Yes
Grout Curtain	Yes	Yes	Could be significantly less than slurry walls because of Hanford porous soil	Ability to control grout placement is limited	No
Sheet Pilings	Yes	Yes	Uncertain; panels are difficult to seal and often leak	Unlikely ability to install in Hanford rocky soils	No
Freeze Wall	Yes	Has not been used in hazardous waste site remediation	Uncertain; technology has not been applied to similar situations	Technology requires installation of 800 holes, 120 feet deep; drilling would require over 40 rig years; not cost effective	No
Permeable Treatment Beds	Yes	Has not been demonstrated at field-scale	Uncertain due to lack of performance data	Limited to shallow depths	No

Table 5-1 Screening of Technologies and Process Options (Page 3 of 3)

Process Option	Technical Feasibility, Timeliness	Technical Feasibility	Protectiveness	Technical Feasibility, Institutional Considerations	Retain Process Option for Detailed Analysis?
	Is Process Option Commercially Available?	Has Process Option Been Used in Similar Circumstances?	Is Process Option Sufficiently Effective?	Is Process Option Implementable?	
Hydraulic Control					
Extraction Wells	Yes	Yes	Yes	Yes	Yes
Extraction Trenches	Yes	Used in shallow applications	Yes	Depth to groundwater makes this impracticable	No
Miscellaneous					
Strontium biosorption	No	No	Unknown; no performance data available	Unknown; no performance data available	No
Solvent extraction with ionizable crown ethers	No	No	Unknown; no performance data available	Unknown; no performance data available	No
Wetlands bioassimilation	No	No	Unknown; no performance data available	Unknown; no performance data available	No

Notes:
1. Consider as an option for ion exchange or reverse osmosis pretreatment to remove suspended solids
2. Consider as an option for ion exchange or reverse osmosis liquid waste treatment for volume reduction
3. Consider as an option for ion exchange or reverse osmosis liquid waste solidification treatment
* No current treatment options for practicable removal of tritium from air are available.

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6.0 DETAILED ANALYSIS OF REMOVAL ACTION ALTERNATIVES

The alternative technologies that have passed the initial screening must undergo a more detailed analysis to select the removal action alternative to be implemented. Each alternative is evaluated with respect to the four selection criteria:

- technical feasibility
- cost considerations
- institutional considerations
- environmental impacts.

Each of these criteria is described briefly as follows (EPA 1987a):

<u>Technical feasibility</u>

- ability to comply with ARAR
- effectiveness in reducing toxicity, mobility, or volume of contamination
- demonstrated performance and reliability under similar conditions
- useful life
- constructability
- operating and maintenance (O&M) requirements
- environmental effects on performance
- sensitivities and uncertainties.

<u>Cost considerations</u>

- capital costs
- O&M costs
- present worth
- cost uncertainties.

<u>Institutional considerations</u>

- ability to achieve removal action objectives
- regulatory concerns about the technology
- permitting requirements
- safety
- timeliness.

<u>Environmental Impacts</u>

- impacts of the removal action on
  - topography and surface drainage
  - geology
  - soils
  - surface water hydrology and quality

- groundwater hydrology and quality
- meteorology and air quality
- biological resources
- cultural resources
- land and water use
- visual resources.

Removal action technologies that passed screening (Section 5.0) are assembled into alternatives for evaluation and comparative analysis. The alternatives are assembled into major technology types (e.g., pump and treat, vertical barriers). The pump and treat alternative includes numerous suboptions for number and location of pumping wells, treatment processes, and treated water disposal schemes. Not all possible combinations of extraction, treatment, and disposal options are evaluated because of the cumbersome nature of the process and lack of benefit of examining all permutations. Instead, the pump and treat technology options are evaluated in three modules: pumping options, treatment options, and treated water disposal options. Specific options from each module are then combined to allow evaluation of alternatives that span the full range of benefits and cost. Once alternatives are compared, selection of a preferred alternative is made by assessing the advantages, disadvantages, uncertainties, and sensitivities of each option and arriving at a selection that is cost-effective for the benefit achieved.

The list of alternatives evaluated in detail is given as follows:

Alternative 1 - No Action

- Continued groundwater monitoring and access control.

Alternative 2 - Pump and Treat

- Pumping Options:
  - five wells
  - three wells.

- Treatment Options:
  - ion exchange
  - reverse osmosis.

- Treated Water Disposal Options:
  - river discharge
  - new N Area crib
  - N Area injection wells
  - new 200 Area crib.

Alternative 3 - Vertical barrier

- Slurry Wall.

Alternative 4 - Hydraulic control

- Upgradient pumping wells.

All alternatives include continued groundwater monitoring and access control. For purposes of detailed analysis, a 10-year project life is assumed because the removal action is considered an interim response until a final remedy is implemented for the 100-NR-2 operable unit. An objective of this ERA is to implement an alternative that contributes to the efficient performance of the final remedial action. While the ERA does not have to comply with the cost and time limitation defined under CERCLA for fund-financed actions, the ERA should be reevaluated in the future for possible conversion to an IRM.

The cost estimates that support the evaluations provide a level of accuracy of +50% to -30%, which is typical of the types of estimates performed for CERCLA FS. Wherever possible, common assumptions are used for estimates and all costs are given in 1993 dollars. Cost estimating details, including assumptions and sources of costs, are provided in Appendix A. Caution should be used in interpreting the estimates, because the intent at this stage of evaluation is to assess costs in <u>relative</u> terms as opposed to <u>absolute</u> terms. That is, the costs should not be considered for their absolute accuracy because more definition and design are needed, especially in assigning indirect costs associated with Hanford installations. However, in relative terms, the costs are sufficiently accurate to make comparisons and judgements regarding the cost-effectiveness of alternatives. The cost uncertainties associated with each alternative or option are discussed in the specific sections where sufficient information is available to evaluate uncertainties.

The general approach to cost estimation assumes that removal systems for N Springs are treated as environmental projects, not as installations of permanent nuclear facilities. Where noted, Hanford labor rates have been used in the labor cost estimate, and additional costs associated with handling radioactively contaminated materials have been considered, where appropriate. In general, the cost estimates reflect an assumption that the level of design and system complexity are minimized to provide systems which, while offering quality in construction and implementation, are consistent with the objectives of an ERA.

The monitoring program discussed for the no action alternative is also assumed to apply to the other alternatives being evaluated. The monitoring program may be expanded to include new wells to monitor the performance of the ERA. Specification of changes to the current monitoring program would be made in the ERA design phase.

The following subsections document the detailed analysis of the four alternatives listed above.

6.1 ALTERNATIVE 1 - NO ACTION

6.1.1 Description

The no action alternative implies no removal action: however, groundwater monitoring and institutional access/administrative controls would continue through the assumed period of performance (10-year project life). This alternative will not reduce the flow of contaminants to the river through the springs. However, because the principal contaminants are radionuclides, they will eventually attenuate through radioactive decay. Soil adsorption is also a factor in the eventual release of strontium-90 to the river. As strontium-90 contaminated groundwater travels through the soils, the contaminant is adsorbed and desorbed in the soil. The net effect will be long-term slow release of strontium-90 to the groundwater.

The monitoring program presently in place will continue. The program consists of the following elements:

- yearly monitoring of the N Springs
- quarterly groundwater well monitoring
- bi-weekly radionuclide effluent analysis of N Springs discharges to the river
- continuous dosimeter surveys along the perimeter fences and ropes
- quarterly radiation surveys along the outer perimeter fences of the cribs/trenches
- annual radiation surveys around the inner perimeter rope of both trenches
- continuous air sampling with monthly analysis.

Connelly et al. (1991) developed a simulation of the groundwater flow and strontium-90 transport in the N Springs area. The PORFLO-3 groundwater flow and transport model was used for this modeling effort. The model simulates the groundwater flow system and contaminant transport utilizing user inputs for groundwater flow and contaminant transport parameters (e.g., hydraulic conductivity, groundwater gradient, contaminant sorption coefficient, etc.). As with all models, this model is an approximation of the groundwater flow and contaminant transport at N Springs.

Assumptions regarding the geometry of the model, such as source dimensions, were generalized due to internal model constraints. The groundwater flow portion of the model was calibrated by comparing simulated arrival times of a nonsorbed radionuclide and water table elevations in July 1969 to observed field data reported in Crews and Tillson (1969). The transport portion of the model was calibrated to match the strontium-90 concentrations observed at the N Springs. The calibration was ended in 1974 when it appeared that the model was predicting the values actually observed at N Springs. The simulation estimated an arrival time of strontium-90 that was 4 years less than that observed and, therefore, overpredicted the strontium-90 concentration.

Following calibration, the PORFLO-3 model was run to predict strontium-90 concentrations in the future. Using 1990 as the base case, strontium-90 concentrations at the river gradually decrease from 6,200 pCi/L in 1990 to about 1,000 pCi/L in 10 years. A plot of groundwater levels and strontium-90 concentrations between the 1301-N LWDF and the N Springs for the year 2002 is shown on Figure 6-1. Comparisons of actual strontium-90 concentrations observed at N Springs, during 1990 and 1993, with those predicted by Connelly et al. (1991), show that the model does predict consistent concentrations at the N Springs. The concentration gradient near the river is high, probably reflecting river water dilution. Concentrations upgradient from the N Springs appear to be predicted at concentrations higher than found in actual groundwater samples. The PORFLO-3 model assumes a homogeneous and isotropic aquifer system when in fact it is not. The variability in predicted versus actual groundwater strontium-90 concentrations may be the result of heterogeneities in aquifer properties and variation in sorptive/desorptive characteristics of the aquifer material.

Additional details of the model setup, calibration, and results are found in Connelly et al. (1991). The strontium-90 distribution shown on Figure 6-1 does not exactly match what would be expected based on the groundwater levels shown on the same figure. This is because of the very large volumes of water discharged from 1964 to 1991 created an artificial groundwater mound that distributed the strontium-90 radially around the disposal facility. The figure reflects this distribution. Over this 12-year period, the model predicts the total strontium-90 flux at 33 ft from the river, with no abatement action taken, to be 12.6 Ci (see Table 6-1). Connelly et al. (1991) states the conclusion of the modeling effort as follows:

> "...without additional discharges to the LWDF, the plume should remain where it currently is and decay with time."

This model should only be used as an indicator of general groundwater flow and contaminant transport, such as how far does the plume move with time or does one alternative restrict groundwater flow better than another. The strontium-90 concentrations predicted by the model represent concentration estimates for the groundwater; they should not be taken as absolute predictions of subsurface concentrations but rather as indicators. The model generalized many of the vadose zone and aquifer characteristics. Uncertainties in the natural hydrogeologic system for such physical parameters as the sorption coefficient and longitudinal and transverse dispersivities, and aquifer properties such as hydraulic conductivity, heterogeneities, anisotropies result in uncertainty in the absolute predictive ability of the model.

Inclusion of this option in the evaluation satisfies the National Contingency Plan (NCP) requirement that a no action alternative be evaluated as a baseline to which all other alternatives are compared.

6.1.2 Technical Feasibility

Existing administrative and institutional controls in the 100 N Area include site security and access restrictions designed to minimize human exposure to contamination. Currently, the only potential human exposure to contaminated groundwater is in the immediate vicinity of the seeps and springs along the riverbank. While access controls may be effective in reducing human exposure, the level of security is not sufficient to prevent members of the public from intentionally entering the area. Institutional controls also do not prevent exposure to environmental receptors, such as wildlife. The existing monitoring program is considered effective in continually assessing potential human health and environmental effects. Evaluation of the no action alternative against other technical feasibility criteria is given in Table 6-2.

6.1.3 Cost Considerations

Costs associated with institutional controls and continued groundwater monitoring are not included in this analysis because these programs are already in place and because these are common to all the alternatives being evaluated. Thus this alternative is considered to have a zero baseline cost for comparative evaluation purposes.

6.1.4 Institutional Considerations

The evaluation of institutional considerations for the no action alternative is summarized in Table 6-3.

6.1.5 Environmental Impacts

The evaluation of environmental impacts for the no action alternative is summarized in Table 6-4.

6.2 ALTERNATIVE 2 - PUMP AND TREAT

6.2.1 Description

The pump and treat alternative consists of two groundwater extraction options, two treatment process options, and four treated water disposal options. Each of these options is described in the subsections below. An overall process flow diagram for the pump and treat system is presented in Figure 6-2.

6.2.1.1 Pumping Options. Three- and five-well systems are considered for the pump and treat alternative to optimize the cost-benefit. The evaluation determines the relative effectiveness of each pumping option in reducing the contaminant flux to the river. The pumping options were chosen because they represent a reasonable estimate of the system requirements. It is recognized that other options of well numbers and locations may also prove effective. This optimization will be addressed in the design phase if pump and treat is the chosen alternative.

6.2.1.1.1 General Modeling Approach. In both pumping options, the wells are placed 100 ft (30 m) from the river. The actual position of the wells relative to the river will be determined during the design phase, if pump and treat is the chosen alternative. The well position is a balance between the need to pump water with as little river water contribution as possible and the need to reduce the volume of water requiring treatment to as low as possible.

The effectiveness of each pumping case is evaluated using the PORFLO-3 groundwater flow model. This model is the same as discussed for the no action alternative above.

Westinghouse Hanford Company (WHC) (1991) evaluated the three- and five-well pumping alternatives using both analytical and numerical methods. The objective of the WHC (1991) study was to reduce or eliminate the majority of the strontium-90 flux to the river. This was accomplished by developing an extraction well capture zone configuration to encompass the strontium-90 plume within the 1,000 pCi/L concentration contour and to intersect the Columbia River. The number of wells, well spacing, and flow rate were adjusted to create a capture zone with minimization of river water contribution, which contributes to the total water requiring treatment. Based on analytical methods, a multiple well system consisting of five extraction wells, each pumping between 60 and 100 gal/min (330 and 550 m^3/day), spaced 360 to 375 ft apart would accomplish the above objective.

The above extraction system and a three-well system were then modeled using the PORFLO-3 model simulation developed by Connelly et al. (1991) to determine the effects of pumping on strontium-90 release to the river. The two extraction well scenarios modeled were:

- 3 extraction wells, each pumping at 50 gpm (270 m^3/day), total discharge of 150 gal/min (820 m^3/day), spaced 720 ft (220 m) apart

- 5 extraction wells, each pumping at 60 gpm (330 m^3/day), total discharge of 300 gal/min (1,640 m^3/day), spaced 375 ft (114 m) apart.

The extraction wells in both scenarios were placed 100 ft (30 m) from the river and within the 1,000 pCi/L strontium-90 contour. Results of the modeling for the five-well system at year ten are shown on Figure 6-3.

The PORFLO-3 model provided estimates of the annual and cumulative strontium-90 flux across two vertical counting sections located 33 ft (10 m) and 100 ft (30 m) from the river. The sections were 2,800 ft (853 m) long and summed a saturated zone 33 ft (10 m) high. The annual and cumulative mass flux, estimated by the PORFLO-3 model are presented on Table 6-1. Positive values indicate a net strontium-90 mass movement toward the river and negative values indicate net mass movement toward the wells.

The results of the PORFLO-3 modeling for both the three- and five-well extraction systems indicate that they are both effective in reducing strontium-90 flux to the river, the five-well system being approximately 10 times more effective. The five-well system reduces approximately 96% of the strontium-90 flux at the 33-ft flux zone as compared to the no action alternative. The three-well system reduces the flux at this same zone approximately 67% (see Table 6-1).

Uncertainties associated with the above analysis included: hydraulic conductivity, hydraulic gradient, and contaminant distribution, both lateral and vertical. Also, the model considered only a 2,800-ft summation zone; the effects on either end of this zone were not defined. These uncertainties can effect the number of wells required, the location of wells, and the pumping rates. Prior to design additional field testing and modeling are required to reduce these uncertainties.

6.2.1.2 Treatment Options. Two treatment options are evaluated in detail for application to treatment of contaminated N Springs groundwater: ion exchange and reverse osmosis. Each treatment option is described in the following paragraphs.

6.2.1.2.1 Ion Exchange. A conceptual process flow diagram of an ion exchange system for treatment of N Springs groundwater is given in Figure 6-4. A brief discussion is presented in the following paragraphs.

Groundwater pumped from the extraction well system is collected in a flow equalization tank, which is used to ensure uniform contaminant concentrations in the water fed to the ion exchange system and to provide surge capacity. The water from the tank is pumped to a pretreatment filtration system to remove particulates and suspended solids. These solids must be removed to prevent fouling of the ion exchange beds. The filters are precoat type, which generate small volumes of low-level radioactive solid waste requiring disposal.

Three ion exchange columns in parallel (two active columns and a maintenance back-up) are used to remove the strontium-90. Each column contains two types of exchange media: an organic resin for removal of anionic species such as cobalt colloids and a chabazite zeolite for removal of the strontium-90. The zeolite media will also remove calcium, nonradioactive magnesium, strontium, and other minerals in the groundwater. Alkali metals such as potassium and sodium, however, are not significantly adsorbed on either media. The ion exchange media are not regenerated but are periodically removed from the exchange columns and replaced with fresh media. The media are removed hydraulically into a dewatering tank followed by load-out into disposal containers, such as drums or disposal boxes. Fresh media are pneumatically transferred into the ion exchange vessel. The treated water then flows to the disposal system (see Section 6.2.1.3). Spent media and filter wastes are estimated to be about 8,000 ft^3 (225 m^3)[1] per year for a system treating 300 gal/min (1,135 L/m) of groundwater (the five-well system). Solid wastes would be disposed as low-level radioactive solid wastes.

The type of system described above has been used in nuclear power plant applications and has been recently pilot tested at ORNL (Robinson et al. 1990) for treatment of a wastewater that is very similar in composition to the N Springs groundwater. Oak Ridge National Laboratory presently treats a 150-gal/min wastewater stream with a regenerative ion exchange system. However, they have found that evaporation of the secondary waste is costly (about $0.5M/yr total disposal cost) (Robinson et al. 1990). The pilot tests using nonregenerative chabazite zeolites showed potential disposal cost savings of about 80%. Oak Ridge National Laboratory plans to install the zeolite-based system at their facility in the future.

The ORNL system was designed to remove the strontium-90 to 300 pCi/L to meet the requirements of DOE Order 5400.5; the pilot testing verified that those levels could be met. However, the N Springs target performance level is the proposed strontium-90 MCL of 42 pCi/L. The vendor of the proposed system was unwilling to state that the ion exchange system could meet the desired performance level without treatability testing. The vendor stated that the proposed system could produce water <270 pCi/L. Therefore, the ion exchange system performance remains a technical uncertainty at this point.

Because essentially all of the dissolved material removed in the ion exchange columns is other than the target contaminant strontium-90, the size of the treatment system and the generation of secondary waste will vary proportionately to the volume of groundwater treated. For example, the treatment system for the three-well pumping scenario (150 gal/min) is 50% the size of the five-well treatment system (300 gal/min) and generates correspondingly less secondary waste.

6.2.1.2.2 Reverse Osmosis. A conceptual process flow diagram for a reverse osmosis groundwater treatment system is shown in Figure 6-5.

A flow equalization/surge tank receives groundwater from the pumping wells. The water is pretreated by filtration using 5 micron and 0.5 micron cartridge filters in series to remove suspended solids. The pH of the groundwater is then adjusted to 5.0 using acid, which prevents precipitation of salts as the concentration of carbonates is increased in the reject stream. Formation of carbonate and sulfate salts will clog the membranes and greatly reduce operating efficiency. Sodium hexametaphosphate is also added to inhibit crystallization of other types of salts that may form as concentration increases in the reject stream.

The chemically treated groundwater is pumped at high pressure into a reverse osmosis unit where processing will produce a concentrated waste stream containing the bulk of the dissolved solids and a stream consisting of demineralized water. The membranes are

[1]Based on assumed total dissolved solids in groundwater of 150 ppm, a 50% solid bottoms stream, and 100% volume increase for solidification.

typically either spiral wound into a cylindrical configuration or are fabricated into hollow fibers. The membranes provide a pore size in the range of one to ten angstroms (0.0001 - 0.001 microns).

The purified water stream (permeate) is discharged via the disposal system (see Section 6.2.1.3), while the concentrate must be processed further for volume reduction. The concentrated waste stream represents about 10% of the feed stream, although the exact quantity of waste is subject to determination in a treatability study. It is also uncertain whether the reverse osmosis system can meet the treatment performance requirement of 42 pCi/L. This is subject to determination in a treatability study.

The concentrated waste stream is volume-reduced by evaporation. A single vapor recompression evaporator (electrically heated) is specified for this application (this evaporator is assumed here because of energy efficiency; the actual type of evaporator and power source would be determined in the design phase). The clean condensed vapor from the evaporator is discharged with the reverse osmosis permeate. The evaporator-bottoms stream, which is about 50% solids, is solidified in a Portland cement grout. Based on current groundwater data, the bottoms stream can likely be disposed as a low-level radioactive solid waste. For a 300 gal/min groundwater treatment system, the volume of grouted waste is estimated to be about 8,000 ft^3 per year.

The options of disposing liquid wastes to the existing double-shell tanks (DST), the 242-A evaporator, or both were considered but rejected. The volume of liquid waste would result in an unacceptably large increase in DST wastes. The 242-A evaporator is not currently operating and is considered unavailable for processing any wastes other than the existing tank farm wastes.

6.2.1.3 Treated Water Disposal Options. Treated groundwater from the processes described in Section 6.2.1.2 above will still contain levels of tritium that exceed ARAR (the drinking water MCL for tritium is 20,000 pCi/L and the proposed MCL is 60,900 pCi/L). The tritium levels in the groundwater are not reduced by either treatment process. Currently, there is no known treatment process for removing tritium that can be practically applied to groundwater.

Based on 1991 data, the average tritium concentration in the area of the pumping wells is about 51,000 pCi/L (Schmidt et al. 1992). Upon pumping, the tritium concentrations would likely increase because the center of mass of the tritium plume is still upgradient of the proposed pumping well location(s). Based on 1993 data, the maximum observed concentration of tritium was 80,900 pCi/L, located just downgradient of the 1325-N crib. This could be considered as a conservative maximum concentration that may be expected in an extraction well. Using the proposed MCL of 60,900 pCi/L as the performance standard may allow different disposal options. These other options can be evaluated in the design phase.

Four options are evaluated for disposal of the treated water containing tritium:

- river discharge
- new crib in the N Area
- new injection well(s) in the N Area
- new crib in the 200 Area.

Each of these options is described in the following paragraphs.

6.2.1.3.1 River discharge. Treated water from the treatment unit is collected in a tank, providing a surge capacity of 15 minutes prior to discharge to the river. The effluent is continuously monitored for strontium-90 using an on-line beta counting instrument. The energy of beta particle emissions from strontium-90 is sufficiently different, relative to tritium, that discrimination of strontium-90 is readily achieved. Exceeding pre-set limits for strontium-90 as detected by the monitor would alert the system operator and automatically shut down the system. Once the problem is corrected, the surge tank contents would be reprocessed through the treatment system.

Treated water from the surge tank flows into the river via a buried gravity flow pipeline. The pipeline would be double-wall construction with leak detection systems. It is assumed that the flow would be routed via the existing river outfall (009) or a new outfall. This study assumes use of the existing outfall.

River discharge may require a NPDES permit. Although N Reactor has been operated under an existing NPDES permit since 1980, additional permitting requirements, if any, have not yet been established for river disposal of N Springs treated water. Establishing permitting requirements would require discussions with regulators. In addition, the Tri-Party Agreement Milestone M-17 requires the cessation of liquid effluent discharges by 1995 and may affect the treated water disposal options.

6.2.1.3.2 New Crib in the 100 N Area. Collection and monitoring of treated water is achieved in the same manner as described for the river discharge option.

Treated water from the surge tank would be pumped to a new crib located in the 100 N Area. The crib would be a standard Hanford design located so the discharged water would not affect existing contaminant plumes or contaminant sources. Water discharged to the crib would percolate to groundwater and flow into the river. The travel time of the water to the river would not be sufficient to allow depreciable decay of the tritium.

6.2.1.3.3 New injection wells in the N Area. Collection and monitoring of treated water is achieved in the same manner as described for the river discharge system.

Treated water from the surge tank is pumped to a series of injection wells located in the 100 N Area. The injection wells would be screened over the entire thickness of the Ringold unit 1 aquifer and would be located so that the discharge water would not affect existing contaminant plumes. Water discharged to injection wells would eventually flow into the river. The travel time of the water to the river would not be sufficient to allow appreciable decay of the tritium. In addition, this option may also result in contamination of clean sediments.

If pump and treat is selected as the preferred alternative, other disposal options may be considered in the design phase. An example is a recirculation system proposed through regulatory comment. This system would consist of a series of extraction wells coupled with treatment facilities to remove the strontium-90. The remaining tritiated water would be reinjected upgradient of the extraction wells, presumably near the 1325-N crib. The tritiated water would be contained in an extraction-injection loop which would allow for natural decay of the tritium. Some considerations of this system include the remobilization of contaminants from the sediments underlying the crib and the variability of the extraction rates due to increased groundwater movement from the injection. These issues could be assessed through modeling in the design phase.

6.2.1.3.4 New crib in the 200 Area. Collection and monitoring of treated water is achieved in the same manner as described for the river discharge option.

Treated water from the surge tank is pumped via a cross-country pipeline approximately nine miles to a new crib located in the 200 West Area. This crib is assumed to be in the same vicinity as the one planned for discharging treated wastewater from the 242-A evaporator condensate treatment facility. The crib would be a standard Hanford design. The water would percolate through the soil column and eventually flow to the river through the groundwater system. However, since the travel time to the river is long (model estimates at 105 years), the tritium would decay to well below drinking water limits by the time it reached the river. The estimated travel time of 105 years is about 8.5 half-lives of tritium. At the maximum expected concentration of 80,900 pCi/L, only about two half-lives of decay would actually be required to meet the drinking water MCL for tritium. While the new crib could be located somewhat closer to the river to achieve a travel time of about 50 years, the basis for this study assumes the 200 West Area location.

6.2.2 Technical Feasibility

Pump and treat may contribute to final remediation. Technical feasibility of each of the pump and treat pumping options, treatment options, and disposal options are discussed in the following subsections.

6.2.2.1 Pumping Options. Technical feasibility for each of the three pumping options are summarized in Table 6-5.

6.2.2.2 Treatment Options. Both ion exchange and reverse osmosis are considered to be implementable and effective for removing the strontium-90 from N Springs groundwater. However, with either process, the ability to meet the 42 pCi/L discharge limit cannot be determined without performing treatability studies on samples of actual groundwater. It is likely that both processes could be made to meet the discharge limit, although perhaps at the expense of greater operating severity and cost. The reverse osmosis system is much more complex than the ion exchange system because of the need for chemical pretreatment, secondary volume reduction by evaporation, and waste solidification. Table 6-6 summarizes the evaluation against the technical feasibility criteria.

6.2.2.3 Treated Water Disposal Options. The evaluation of technical feasibility of all four treated water disposal options is summarized in Table 6-7.

6.2.3 Cost Considerations

Cost estimates for all of the options evaluated in this alternative are summarized in the Tables 6-8 through 6-14. Cost estimate assumptions, sources, and details are documented in Appendix A. All present worth values are based on a discount factor of 10% and a project life of 10 years.

6.2.3.1 Pumping Options. Costs for the extraction system associated with the pump and treat alternative are given in Table 6-8.

6.2.3.2 Treatment Options. Costs for the treatment system options associated with the pump and treat alternative are given in Tables 6-9 and 6-10.

6.2.3.2.1 Uncertainties. Cost estimates for both the ion exchange and reverse osmosis systems were based on vendor quotations. The ion exchange costs are based on knowledge gained in pilot testing at ORNL. Uncertainty exists for ion exchange in the consumption of media and associated waste generation rate.

Both capital and operating costs for the reverse osmosis system are more uncertain than for ion exchange, especially the operating costs. The vendor operating cost quotes span a wide range. One vendor quoted the total system O&M costs at 3-5 cents/gallon for a system which uses an evaporator and vacuum drier. Based on the high value, the annual O&M cost would be nearly $8 million for the five-well system. This is almost an order of magnitude higher than the costs developed by different vendors. The discrepancy is not resolved and is indicative of substantial cost uncertainty for the reverse osmosis system at this conceptual level of design.

Disposal costs represent a significant fraction of the costs for the ion exchange treatment system. Disposal costs are generated based on current circumstances at Hanford, e.g., disposal to existing facilities. However, the Environmental Restoration Disposal Facility (ERDF) may allow less costly disposal of the treatment residues. The ERDF schedule lags the N Springs ERA schedule, but storage of wastes with disposal to ERDF in the future may prove less costly than the proposed disposal to existing facilities. However, the data to confirm this are currently unavailable. The progress of the ERDF and the development of disposal costs should be reevaluated in the design of the pump and treat system to better define disposal costs.

6.2.3.3 Treated Water Disposal Options. Costs for the treated water disposal options associated with the pump and treat alternative are given in Tables 6-11 through 6-14.

6.2.4 Institutional Considerations

Evaluation of institutional considerations for the pumping, treatment, and disposal options are discussed in the subsections below.

6.2.4.1 Pumping Options. The evaluation of institutional considerations for the two pumping options is summarized in Table 6-15.

6.2.4.2 Treatment Options. The evaluation of institutional considerations for the two treatment options is summarized in Table 6-16.

6.2.4.3 Disposal Options. The evaluation of institutional considerations for all four treated water disposal options is summarized in Table 6-17.

6.2.5 Environmental Impacts

Environmental impacts for the pumping, treatment, and treated water disposal options are discussed in the subsection below.

6.2.5.1 Pumping Options. The evaluation of environmental impacts for the pump and treat pumping options is summarized in Table 6-18.

6.2.5.2 Treatment Options. Neither treatment option is considered to have significant environmental impact. Ion exchange does not produce air emissions; the reverse osmosis system has the potential to release tritium to the air from the evaporator. Secondary waste is produced from both which is solidified, packaged, and buried as low level radioactive waste.

6.2.5.3 Disposal Options. The evaluation of environmental impacts for the pump and treat disposal options is summarized in Table 6-19.

6.3 ALTERNATIVE 3 - VERTICAL BARRIERS

Slurry walls were retained as the single process option for consideration in the vertical barrier alternative. Detailed analysis of this alternative is discussed in the subsections below.

6.3.1 Description

The slurry wall option works as a barrier to groundwater flow and creates a diversion of groundwater flow upgradient. The slurry wall causes the groundwater flow direction to change from mainly parallel to the location of the wall to more perpendicular. This acts to reduce the groundwater gradient behind the wall, which lowers groundwater flow velocity behind the wall and thus lengthens the travel time for contaminants to reach the river. At the ends of the wall, the gradient will increase and result in higher than normal flow velocities.

This results in faster contaminant travel times at the wall ends. Uncertainties to this alternative are the extent of the groundwater gradient reduction behind the wall, the effects of the increased flow velocity at the wall ends, and wall length.

The slurry wall option for N Springs was modeled using the PORFLO-3 groundwater flow and transport model. This model is same as discussed in the no action alternative with the barrier wall added to the base case. The modeled barrier is a 2,800-ft (853-m) long wall nearly spanning the width of the strontium-90 plume at approximately 100 ft (30 m) inland from the river. The model assumes a slurry wall hydraulic conductivity of 3 x 10^{-3} ft/d (10^{-6} cm/sec) and a retardation coefficient of 43.3. The wall reduces the contaminant flux to the river by redirecting the groundwater flow around the wall. This results in a reduction of the groundwater gradient behind the wall which reduces the groundwater flow velocity. Strontium-90 tends to bind with the soil and, when combined with the decreased gradient and flow velocity, transport of strontium-90 to the river is reduced. The wall does not completely prevent strontium-90 transport to the river, however modeling results indicate that strontium-90 flux to the river is significantly reduced.

To determine the barrier wall effectiveness, two vertical contaminant flux counting sections were established to add all of the groundwater and strontium-90 flow passing through those sections. The sections were set at the position of the barrier wall (100 ft [30 m] from the river) and at 33 ft (10 m) from the river. Each plane was the same length as the wall. Strontium-90 flux through these planes is tabulated on Table 6-1. The negative flux values reported for the barrier wall, 100 ft (30 m) from the river, are the result of strontium-90 adsorption into the wall. While the wall will adsorb some strontium-90, the extent of adsorption has not been estimated. Once equilibrium is reached in the wall, in year 10, a very small positive flux of strontium-90 occurs. Based on the strontium-90 flux values at the 33-ft (10-m) flux section position, the slurry wall restricts 71% of the strontium-90 flux to the river as compared to the no action alternative. The strontium-90 flux difference between the 100-ft (30-m) and 33-ft (10-m) sections are a result of strontium-90 leaching from the soils between these two sections. This suggests that the closer the wall is to the river the more strontium-90 mass that will be contained.

Results of the modeling for the year 2002 are shown on Figure 6-6. The figure illustrates the water level configuration and contaminant distribution. It should be noted that the contaminant distribution does not completely match the groundwater flow direction because of the large groundwater mound that was present during LWDF operation (this mound has now dissipated). The radial strontium-90 distribution is due to the original liquid waste disposal patterns at the 1301-N LWDF.

Comparison of Figure 6-6 (Slurry Wall Alternative) and Figure 6-1 (No Action Alternative) for the zone between the wall and the river suggests that no benefit from the wall is realized. This is not supported by the model results for strontium-90 flux as presented in Table 6-1. Figure 6-6 depicts groundwater concentrations at a particular point in time, while the flux values (Table 6-1) represent the total strontium-90 flowing across the 33 ft summation section line. The key to understanding the performance of the wall is to consider the strontium-90 flux reduction as shown on Table 6-1. Table 6-1 shows a reduction of strontium-90 flux to the river with the wall in place to be approximately 8.9 Ci, at a measurement section 33 ft from the river.

The strontium-90 concentrations shown on Figure 6-1 and 6-6, between the modeled wall and the river, are the result of contaminants which have sorbed to the soils and are desorbing through the influx of non-contaminated river water. These sediments will continue to release strontium-90 through the expected duration of the ERA. In addition, the concentrations between the wall and the river are suspect. It would be expected with the wall in place that river action would result in a greater degree of aquifer flushing in this zone resulting in decreasing concentrations with time. This discrepancy is due to river stage assumptions made in the model. The model assumes only four river stage changes during a calendar year. This does not account for the high degree of flushing which occurs due to the frequent and rapid river stage changes which occur daily, monthly, and seasonally. This same uncertainty also applies to the flux calculations presented on Table 6-1.

The model and associated flux values also do not account for the strontium-90 that may flow around the ends of the wall. The potential exists that concentrations higher than those estimated by the model may flow around the wall. Additional modeling is required to more fully quantify the flux reduction as a result of the slurry wall.

The wall modeled with PORFLO-3 was retained for detailed analysis, except that the location of the wall is assumed to be 200 ft (60 m) from the river instead of 100 ft (30 m). This was done to avoid placing the wall in the 100-year floodplain which would trigger wetlands analysis and to allow for easier construction in the more level terrain at 200 ft (60 m) back from the river (100 ft [30 m] from the river is on a steep slope). Locating the wall further back should not affect the ability to reduce strontium-90 flux from the area of the cribs but would result in more contamination (between the wall and the river) being flushed into the river from already contaminated sediments as a result of fluctuating river stages.

Actual wall placement and length would be considered in the design phase through additional modeling. Placement of the wall closer to the river has several advantages including:

- lower depth to the confining layer resulting in lower costs
- reduced risk of drilling difficulties from boulders
- increased production rates during construction
- reduced strontium-90 flux to river by minimizing contaminated soil between the wall and the river.

From a technical and cost point of view, locating the wall closer to the river (in the floodplain) is advantageous but risks administrative delays in assessing wetlands impacts. The approximate location of the wall for this proposal is shown in Figure 6-7. At its base, the wall would be keyed approximately 3 ft (1 m) into the underlying Ringold paleosol/overbank deposit as shown in Figure 6-8. The wall would be designed to provide a permeability of 10^{-7} cm/sec which would severely restrict the movement of contaminant-laden groundwater through the wall. At the proposed location, the total depth from ground surface is estimated to average about 104 ft (32 m). Placement of the wall in the floodplain would reduce the cost of the wall and its depth to about 50 ft (15 m).

Two types of construction are considered for installation of a slurry wall at N Springs, conventional excavation and deep soil mixing. Each type of installation is discussed in the following paragraphs.

6.3.1.1 Excavated Slurry Wall. Conventional slurry wall installation involves the excavation of a trench to a confining layer using a thickened bentonite slurry for excavation support. The trench is sequentially backfilled with a mixture of excavated soils and bentonite or a combination of soil, bentonite, and cement in the case of a plastic concrete wall.

Soil is excavated using a backhoe or an excavator, such as a clamshell or dragline, depending upon the depth required. The N Springs slurry wall may require the latter because the total depth of the wall at 200 ft (60 m) from the river is beyond the maximum 70-ft (21-m) reach of backhoes. Backhoes could be used if the wall is placed approximately 50 ft (15 m) from the river.

As excavated soil is removed from the trench, it is placed on the adjacent ground surface. Bentonite is added to these backfill soils in both dry form and as slurry for moisture conditioning; the bentonite and soils are mixed by plowing with a bulldozer or in a pugmill. Upon completion of mixing, backfill material is pushed into the trench displacing the bentonite slurry mixture and forming a contiguous mass of low permeability wall. Excess soil is generated that may require disposal; approximately 33% of the total excavated volume for a soil-bentonite wall and up to 60% for a soil-bentonite-cement wall is excess soil (Spooner et al. 1985). To minimize the volume of contaminated soil produced, materials could be segregated so that the uncontaminated vadose zone soil would make up most of the soil not returned to the trench.

To make a suitable slurry, the fines content of the soil must be in the range of 10% to 20%. Hanford formation and Ringold Formation soils are lower in fines than required; therefore, some import of fine soil materials or an increase in the amount of bentonite in the slurry mixture is needed to construct the wall. This will likely increase the volume of excess soil requiring disposal. Contaminated soil will have to be disposed as a low level radioactive waste in accordance with DOE Order 5820.2A. In addition, saturated soils excavated from below the water table will require dewatering; the contaminated water fraction will also require suitable disposal.

6.3.1.2 Deep Soil Mixing. Deep soil mixing is a relatively new technique and is available commercially for construction of vertical barriers with properties similar to slurry walls. The equipment used for deep soil mixing consists of a kelly bar and a specially designed large diameter (e.g., 5 to 8 ft [1.5 to 2.4 m]) auger containing injection nozzles. The assembly is mounted on a crane and is initially driven into the soil mechanically to the depth required. The tool is then withdrawn partially (to approximately half the depth of the wall), slurry material injection is initiated as the auger is again driven downward, and slurry injection continues through withdrawal of the auger. The auger mixes the slurry with the soil as it is driven downward and pulled upward. This method of operation ensures thorough mixing of the soil with slurry materials, such as bentonite or combinations of bentonite and cement.

The slurry wall is completed by auguring and mixing a series of overlapping holes. For the N Springs application, the completed wall would be 3 to 5 ft (1 to 1.5 m) thick. A tool which measures 5 ft (1.5 m) in diameter is specified for the purposes of costing the N Springs application. According to a vendor, tools of this diameter are capable of operation in Hanford's rocky soils and should meet the minimum requirement of 10^{-6} cm/sec permeability. While Hanford soils are rocky, they are also unconsolidated, which is an advantage to the auguring approach. Also, according to the vendor, the probability of achieving a permeability of 10^{-7} cm/sec is excellent, because a slurry mix with a high percentage of bentonite and imported fines may be designed to fill the interstitial pores, even in coarse, gravelly soils. The mix would require testing however.

The chief advantage to deep soil mixing is that it does not require removal of contaminated soil, thereby eliminating contaminated soil or water disposal problems. Construction costs are comparable to conventional excavation, but potentially much lower when soil and water disposal costs are taken into account. For this reason, further analysis, including cost analysis, will be conducted under the assumption that deep soil mixing will be used for constructing a slurry wall at N Springs.

6.3.2 Technical Feasibility

Deep soil mixing appears to be a preferred slurry wall construction method for Hanford application because it minimizes contaminated soil removal and disposal. Field trials prior to actual installation may be required to demonstrate a 10^{-6} cm/sec permeability. In addition, full-scale field testing could be done to demonstrate the viability of deep soil mixing in Hanford soils. Table 6-20 presents a technical feasibility evaluation of a slurry wall installed by deep soil mixing. The slurry wall may contribute to final remediation; however, if removal of the wall becomes an issue in the future, the technical feasibility and costs will be evaluated at that time.

6.3.3 Cost Considerations

Cost estimates for all of the options evaluated in this alternative are summarized in Table 6-21. Cost estimate assumptions, sources and details are documented in Appendix A. All present worth values are based on a discount factor of 10% and a project life of 10 years.

6.3.4 Institutional Considerations

The evaluation of institutional considerations for the slurry wall option is summarized in Table 6-22.

6.3.5 Environmental Impacts

The environmental impacts for the slurry wall option are summarized in Table 6-23.

6.4 ALTERNATIVE 4 - HYDRAULIC CONTROL

Only one process option was considered for hydraulic control: extraction wells located upgradient from the contaminated groundwater plume. The evaluation of this option is documented in the subsections below.

6.4.1 Description

The upgradient hydraulic control option is analyzed to determine its relative effectiveness in reducing contaminant flux to the river by reducing the flow of water from the contaminated portion of the aquifer. This can be accomplished by reducing the hydraulic gradient.

Upgradient hydraulic control is implemented by placing a series of pumping wells upgradient from the contaminant sources to capture the water flowing into the area. A properly designed pumping system results in lowering of the water table at the pumping wells. The wells are placed sufficiently upgradient so that the pumped water is uncontaminated and, therefore, secondary water treatment would not be required. There is, however, a potential to induce groundwater flow from the area of contamination and increase the area of contamination beyond the current upgradient boundary.

To assess the efficiency of the hydraulic control alternative, the two-dimensional numerical groundwater flow model FLOWPATH (Franz and Guiguer 1991) was used. FLOWPATH assumes two-dimensional, steady-state flow with saturated porous media. The model can be used in heterogeneous anisotropic media. The application of the model for N Springs assumes that the unconfined aquifer system is homogeneous and isotropic.

The model size was set to 5,900 ft by 5,900 ft (1,800 m by 1,800 m). Model boundaries were established as constant head nodes along the left, bottom, and right boundaries. Head values were calculated using an initial head value of 392 ft (119.5 m) in the bottom left corner of the modeled area and a predisposal water table gradient of 0.00095 m/m (Connelly et al. 1991), trending southwest to northeast across the model. The river boundary was set as surface water boundary nodes. In the FLOWPATH model, a surface water body node allows the water to set a water surface elevation, bottom elevation, and a streambed leakage factor. For this model, the river stage elevation was set at 385 ft

(117.5 m) at the upstream node at the left of the model. A river gradient of 0.000256 m/m (Connelly et al. 1991) was applied to determine river elevations downstream. A river depth of 30 ft (10 m) and a leakage factor of 6.7 was used to further define the nodes. Aquifer properties used in the model are the same as those used by Connelly et al. (1991) to model the no action alternative.

The goal of upgradient hydraulic control is to reduce the groundwater flow to the river by at least 50% without causing spread of strontium-90 contamination upgradient toward the pumping wells. Several different upgradient well placement and pumping rate scenarios were modeled to determine the optimum well placement within the constraints of the model. The resulting well configuration and pumping rates are shown on Figure 6-9. The configuration consists of 11 pumping wells set in a radial pattern upgradient from the 1325-N facility. Pumping rates vary from 75 to 150 gal/min. The total flow of all wells is 1,100 gal/min. All pumped water is monitored and discharged directly to the river through a new outfall.

This scenario resulted in a reduction in groundwater flow to the river of approximately 50% within the 1,000 pCi/L concentration contour for the 1990 concentration data and 45% of the groundwater flow within the 42 pCi/L contour. The hydraulic gradients are altered gradually before reaching steady-state. Steady-state conditions would probably be reached in a matter of months; however, more comprehensive modeling is required to precisely determine the time to reach steady-state conditions.

As discussed for the pump and treat options, because the model assumes that the unconfined aquifer is both homogeneous and isotropic, there is some uncertainty in the validity of the final results. The aquifer may have zones of higher or lower conductivity that may have a directional component. This could serve as preferred pathways for groundwater and contaminant flow and could affect the capture zone of individual pumping wells. In the actual system operation, these effects could be mitigated to some extent by varying the pumping rates from individual wells to balance out the hydrogeologic uncertainties.

6.4.2 Technical Feasibility

Hydraulic control may contribute to final remediation. Table 6-24 presents a technical feasibility evaluation of upgradient hydraulic control.

6.4.3 Cost Considerations

Cost estimates for all of the options evaluated in this alternative are summarized in Table 6-25. Cost estimate assumptions, sources, and details are documented in Appendix A. All present worth values are based on a discount factor of 10% and a project life of 10 years.

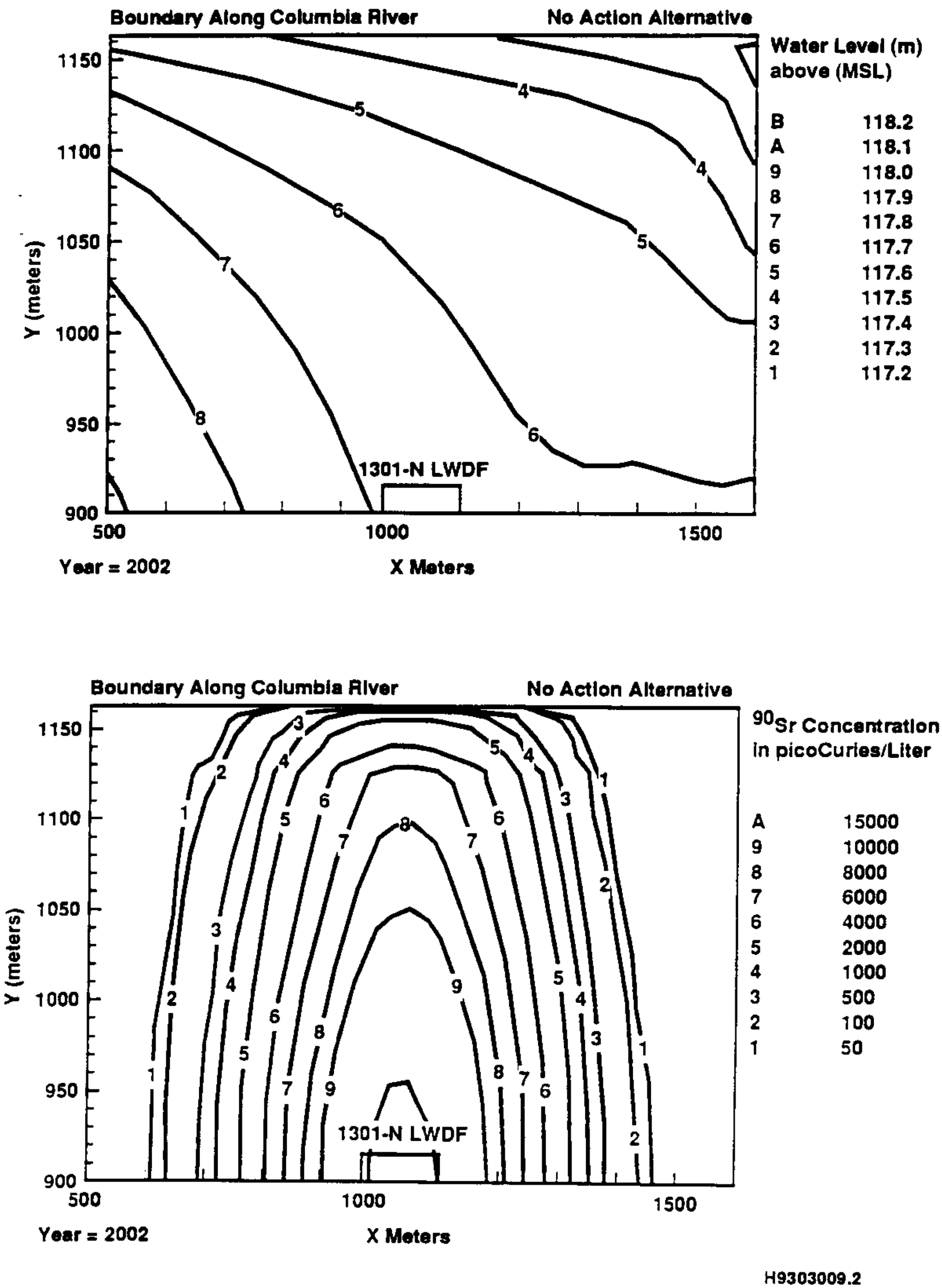
6.4.4 Institutional Considerations

The evaluation of institutional considerations for the hydraulic control option is summarized in Table 6-26.

6.4.5 Environmental Impacts

The environmental impacts for the hydraulic control are summarized in Table 6-27.

Figure 6-1 Groundwater Levels and Strontium-90 Concentration Estimates Based on Groundwater Modeling for the Year 2002 - No Action Alternative



9413135.2104

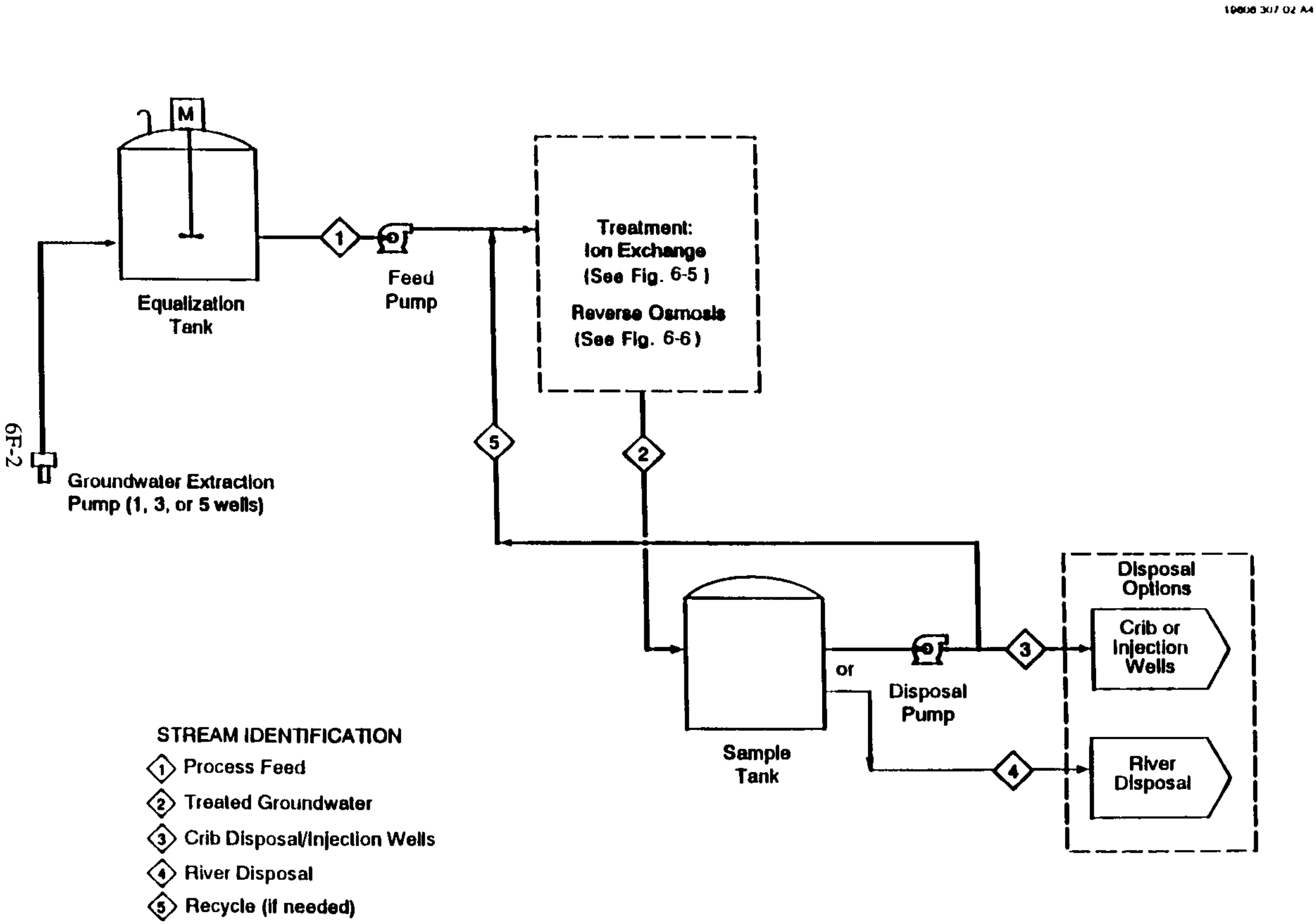
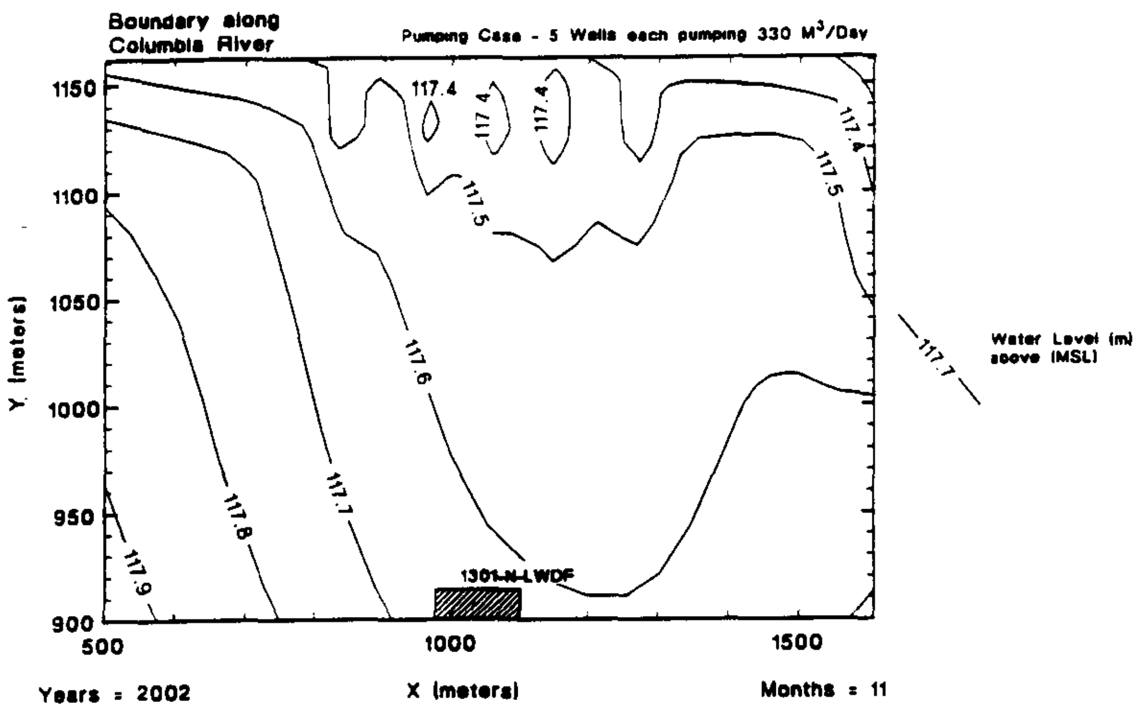
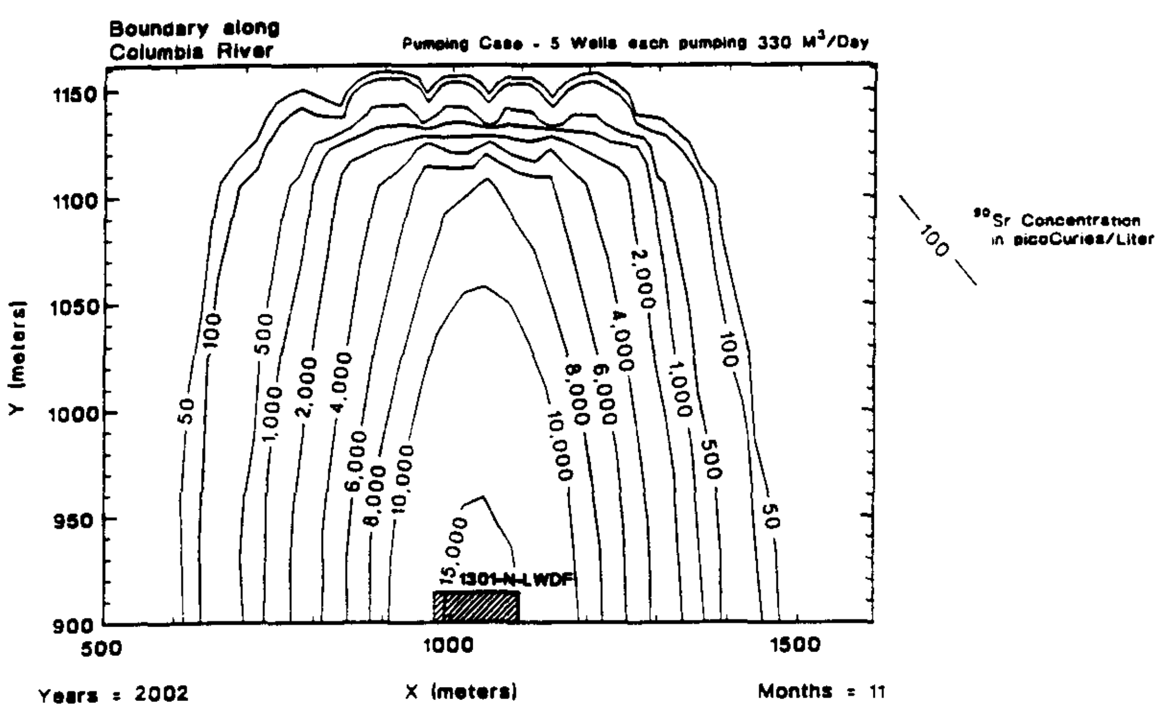


Figure 6-2 Alternative 2 - Pump and Treat Overall Process Flow Diagram

Figure 6-3 Groundwater Levels and Strontium-90 Concentration Estimates Based on Groundwater Modeling for the Year 2002 - Five-Well Pump and Treat System





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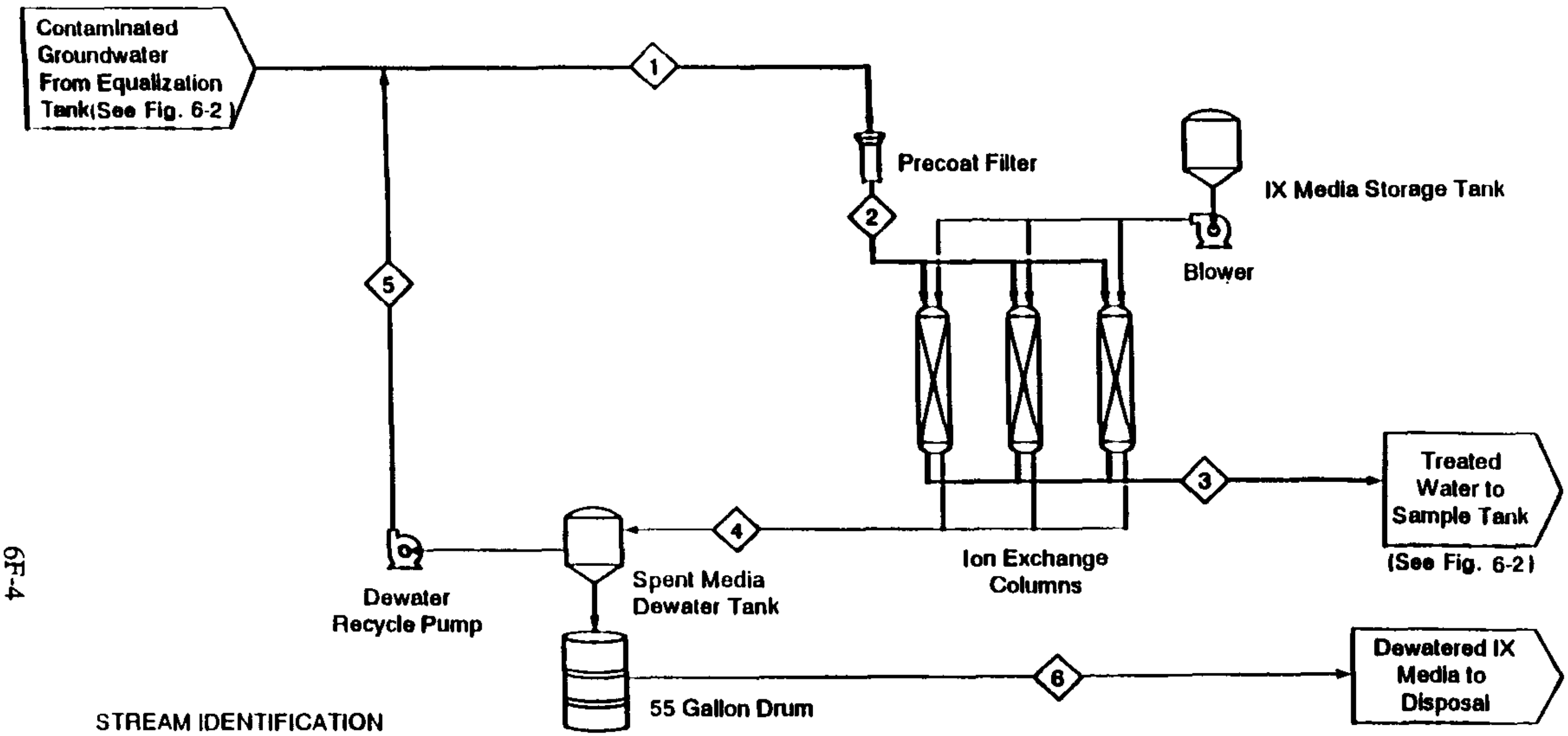


STREAM IDENTIFICATION

1 Process Feed

2 IX Feed, Filtered

3 Clean Discharge

4 Spent Media

5 Dewater Recycle

6 Dewatered IX Media

Figure 6-4 Alternative 2 - Pump and Treat, Ion Exchange Treatment Process Flow Diagram

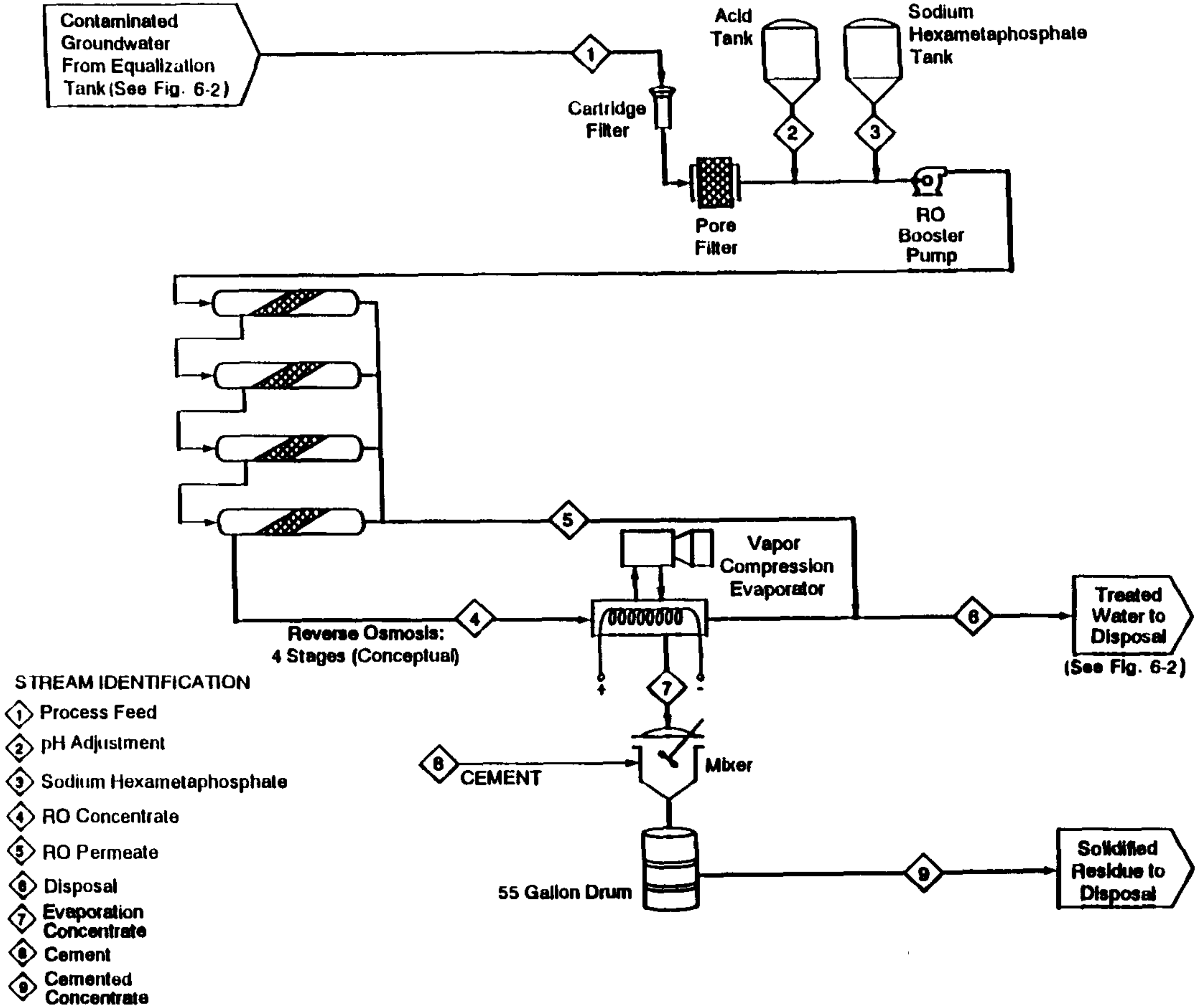


Figure 6-5 Alternative 2 - Pump and Treat, Reverse Osmosis Treatment Process Flow Diagram

Figure 6-6 Groundwater Levels and Strontium-90 Concentration Estimates Based on Groundwater Modeling for the Year 2002 - Slurry Wall Alternative

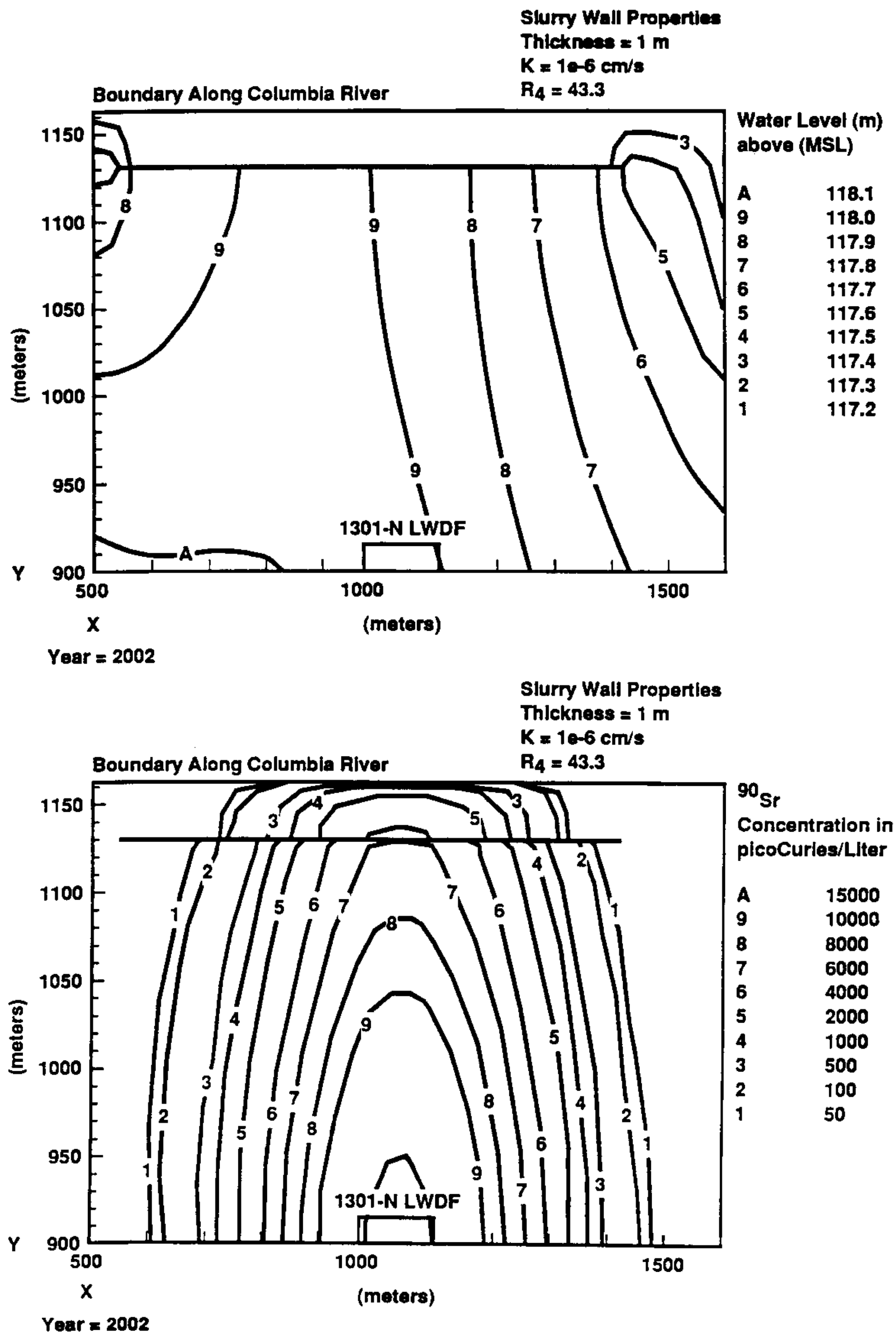
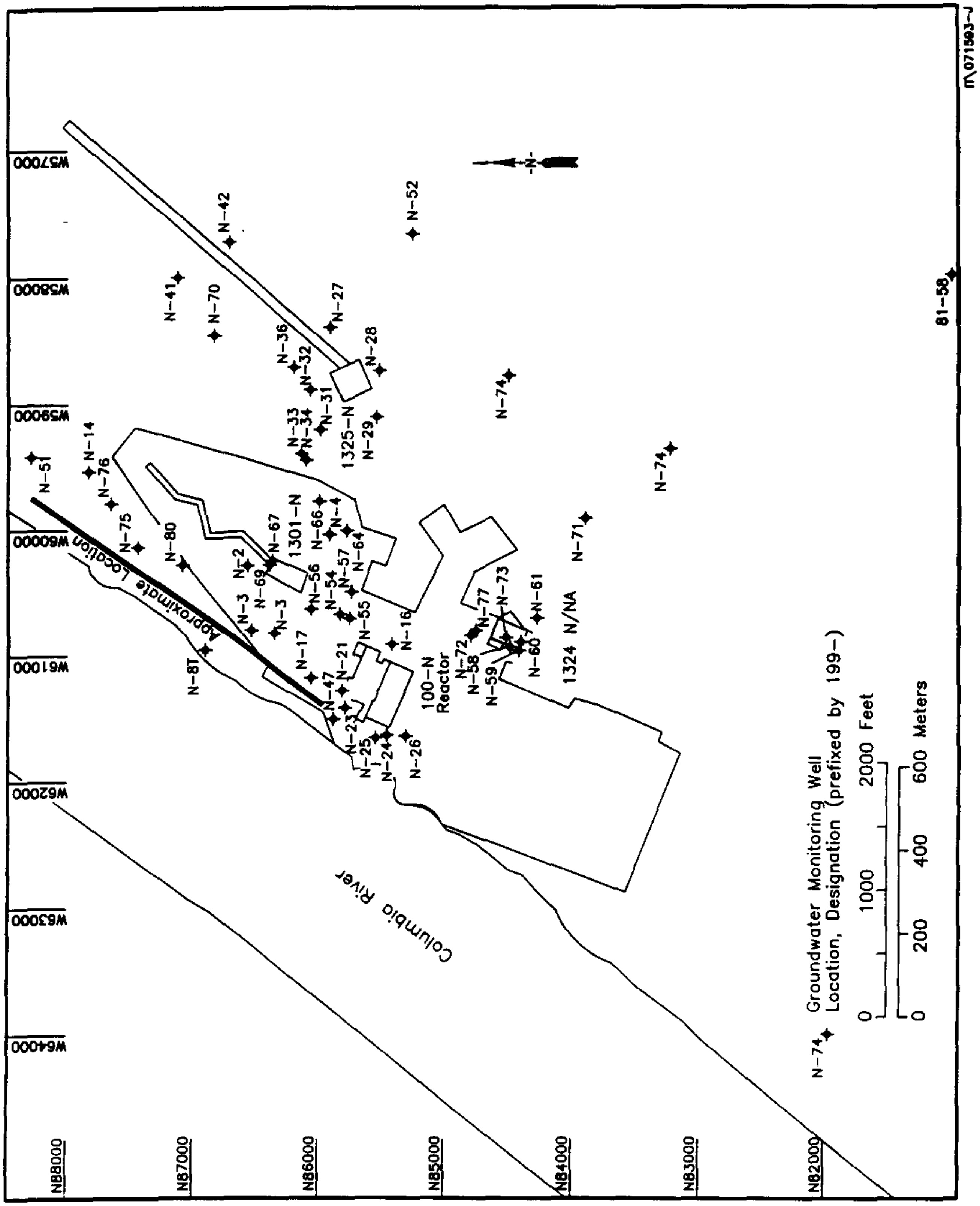


Figure 6-7 Approximate Location of Slurry Wall



9413135.2110

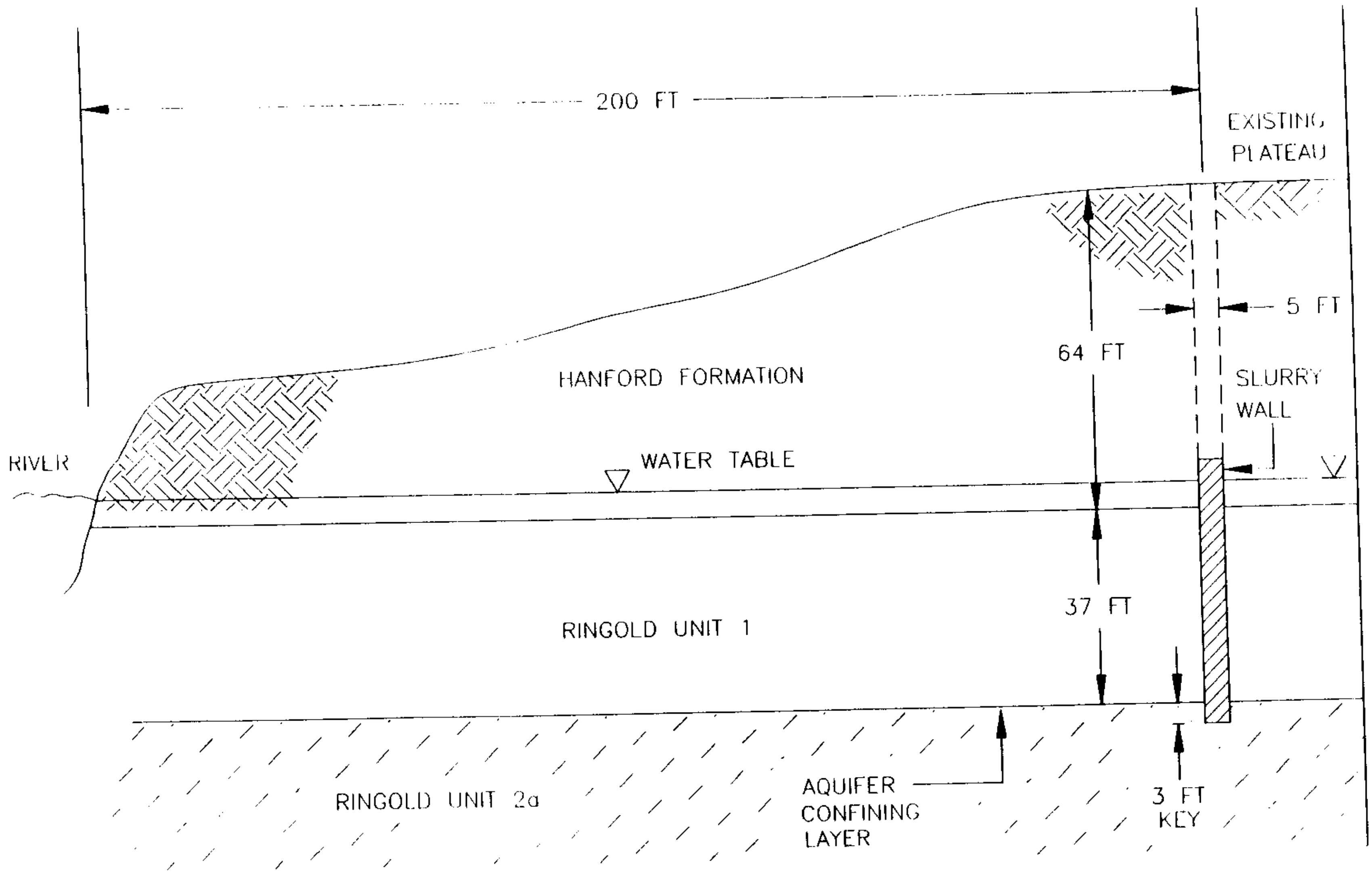


Figure 6-8 Side View, Slurry Wall

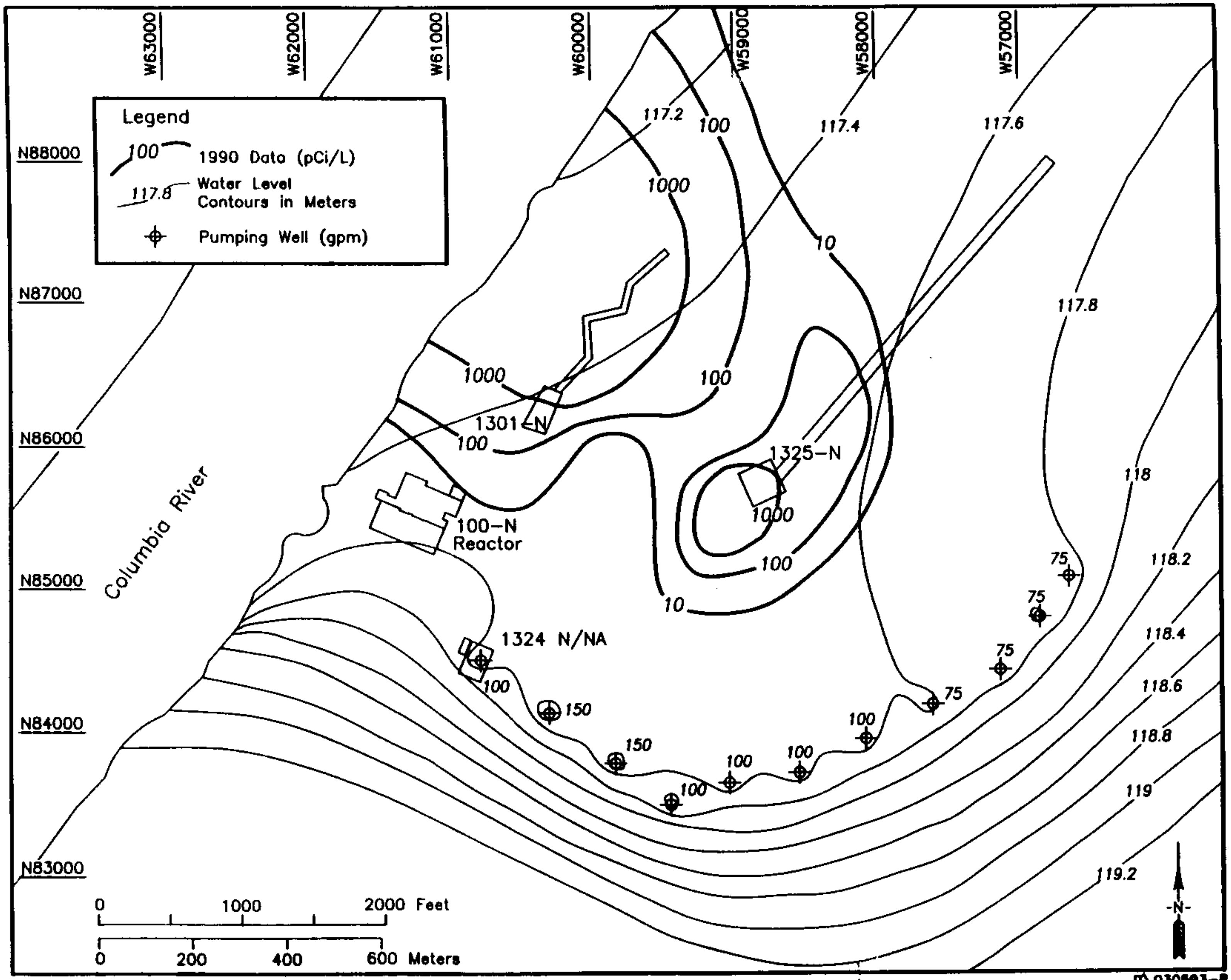


Figure 6-9 Upgradient Hydraulic Control Steady State Hydraulic Head Distribution and Individual Well Pumping Rates

Table 6-1 Annual Strontium-90 Flux (Ci/yr) Through Two Summation Sections Placed 33 and 100 ft from the River as Predicted by Modeling

33 ft From River[2]

Year	No Action	3 Wells	5 Wells	Slurry Wall
1991	1.5	0.42	-0.347[1]	0.37
1992	1.5	0.64	0.080	0.39
1993	1.3	0.54	0.098	0.39
1994	1.2	0.46	0.088	0.38
1995	1.1	0.39	0.075	0.37
1996	1.0	0.34	0.063	0.35
1997	1.0	0.30	0.053	0.33
1998	0.9	0.27	0.044	0.31
1999	0.9	0.24	0.037	0.29
2000	0.8	0.21	0.032	0.28
2001	0.8	0.19	0.027	0.25
2002	0.8	0.17	0.023	0.24
TOTAL	12.6	4.17	0.274	3.70

100 Ft From River[2]

Year	No Action	3 Wells	5 Wells	Slurry Wall
1991	1.0	-0.46	-1.86	-2.99e-3
1992	1.2	-0.22	-1.46	-5.38e-3
1993	1.1	-0.26	-1.22	-5.73e-3
1994	0.9	-0.26	-0.97	-5.06e-3
1995	0.9	-0.23	-0.75	-1.06e-3
1996	0.8	-0.19	-0.57	-3.02e-3
1997	0.8	-0.16	-0.43	-2.06e-3
1998	0.8	-0.11	-0.33	-1.21e-3
1999	0.7	-0.08	-0.25	-4.70e-4
2000	0.7	-0.05	-0.19	1.50e-4
2001	0.6	-0.03	-0.14	7.00e-4
2002	0.7	-0.01	-0.11	1.15e-3
TOTAL	10.2	-2.06	-8.28	-2.50e-2

[1] Positive values indicate a net Sr-90 mass movement toward the river and negative values indicate net mass movement toward the wells or slurry wall.

[2] Both summation sections are for wells or the slurry wall located 100 ft from the river.

Table 6-2 Technical Feasibility Evaluation for No Action Alternative

Criteria	Evaluation
Ability to comply with ARAR	Does not comply with chemical-specific ARAR such as the drinking water MCL
Effectiveness in reducing toxicity, mobility, or volume of contamination	None is attained except that achieved through natural attenuation, primarily through radioactive decay
Demonstrated performance and reliability under similar conditions	No action - not applicable
Useful life	No action - not applicable
Constructability	No action - not applicable
Operation and maintenance requirements	No incremental requirements beyond existing controls and monitoring
Environmental effects on performance	None
Sensitivities and uncertainties	Some uncertainties exist in the data with regard to plume concentration profiles; some uncertainty associated with modeling parameters and modeling predictions, however these uncertainties do not affect this alternative because no actions are taken

ARAR - applicable or relevant and appropriate requirements
MCL - maximum contaminant level

Table 6-3 Institutional Considerations Evaluation for No Action Alternative

Criteria	Evaluation
Ability to achieve removal action objectives	Does not achieve objectives
Regulatory concerns about the technology	Likely unfavorable because ERA objectives are not achieved
Permitting requirements	None
Safety	No action - not applicable
Timeliness	Contamination reduction achievable by natural attenuation only in the long term

ERA - expedited response action

Table 6-4 Environmental Impacts Evaluation of No Action Alternative

Criteria	Evaluation
Environmental impacts on: Topography and surface drainage	No impact
Geology	No impact
Soils	Riverbank sediments will continue to be contaminated
Surface water hydrology and quality	Flow of contamination into the river will continue to impact the near-shore surface water quality
Groundwater hydrology and quality	Contamination will continue to impact local groundwater quality
Meteorology and air quality	No impact
Biological resources	Contamination from springs will continue to potentially impact riparian and aquatic biota
Cultural resources	No impact
Land and water use	Local groundwater and land use will continue to require restriction
Visual resources	No impact

Table 6-5 Technical Feasibility Evaluation for Groundwater Extraction Options

Criteria	Evaluation	
	Five-Well System	**Three-Well System**
Ability to comply with ARAR	Removes contaminated water but does not meet chemical-specific ARAR	Same as five-well system; less contaminated water is removed
Effectiveness in reducing toxicity, mobility, or volume of contamination	Contaminated water flow to the river is greatly restricted (potentially 100% of the >1,000 pCi/L plume)	Contaminated water flow is restricted to a lesser extent than the five-well system
Useful life	Meets requirements	Meets requirements
Constructability	Pumping wells are readily constructable	Same as five-well system; constructability somewhat easier because of fewer wells
Operation and maintenance (O&M) requirements	Operation is not complex; moderate maintenance required for pumps	Same as five-well system; lower O&M due to less wells
Environmental effects on performance	None anticipated	None anticipated
Sensitivities and uncertainties	Uncertainties in plume concentration distribution and hydrologic properties; this option is less vulnerable to uncertainties since it uses five pumping wells	Same uncertainties as five-well system, but more vulnerable to uncertainties since fewer wells are used

ARAR - applicable or relevant and appropriate requirements

Table 6-6 Technical Feasibility Evaluation of Groundwater Treatment Options

Criteria	Evaluation	
	Ion Exchange	Reverse Osmosis
Ability to comply with ARAR	Tritium not removed; ability to meet strontium-90 MCL is uncertain; treatability studies are needed	Same as ion exchange
Effectiveness in reducing toxicity, mobility, or volume of contamination	Effective in removing strontium-90 from extracted groundwater; not effective in tritium removal	Same as ion exchange
Demonstrated performance and reliability under similar conditions	ion exchange has been used extensively for radioactive wastewater treatment	Application for radioactive wastewater is more limited but has been proven
Useful life	Meets requirements	Meets requirements
Constructability	Commercially available systems are designed and constructed as package units by multiple vendors	Commercially available but not to the same extent as ion exchange
Operation and maintenance requirements	System is designed to operate automatically; periodic need for ion exchange media replacement and disposal of spent media	Operation and maintenance are more complex due to evaporator and residue solidification
Environmental effects on performance	System in enclosed building; none anticipated	Same as ion exchange
Sensitivities and uncertainties	Treatability studies required to optimize media selection, determine waste generation rate, and treatment performance	Treatability studies required to determine waste generation rate, membrane life, and treatment performance

ARAR - applicable or relevant and appropriate requirements
MCL - maximum contaminant level

Table 6-7 Technical Feasibility Evaluation of Treated Water Disposal Options (Page 1 of 2)

Criteria	Evaluation			
	River Discharge	N Area Crib	N Area Injection	200 Area Crib
Ability to comply with ARAR	Does not meet tritium MCL	Does not meet tritium MCL	Does not meet tritium MCL	Meets tritium MCL
Effectiveness in reducing, toxicity, mobility or volume of contamination	Effective except for tritium	Effective except for tritium	Effective except for tritium	Effective for all contaminants
Demonstrated performance and reliability under similar conditions	The discharge system is simple and expected to perform reliably	Slightly more complex than river discharge but performance is well established at Hanford	Injection wells are subject to plugging and therefore reliability is somewhat less than other options	Crib performance is reliable; long pipeline to 200 Area is more vulnerable to leaks and other operating problems
Useful life	Meets project goals	Meets project goals	Meets project goals	Meets project goals
Constructability	Easily constructable	Easily constructable	Easily constructable	More difficult constructability because of long pipeline
Operation and maintenance requirements	Very low since it is a gravity flow system	Low since pumping requirements are not high	Low since pumping requirements are not high	High cost for pump operation and maintenance of long pipeline
Environmental effects on performance	None anticipated	None anticipated	None anticipated	None anticipated

Table 6-7 Technical Feasibility Evaluation of Treated Water Disposal Options (Page 2 of 2)

Criteria	Evaluation			
	River Discharge	N Area Crib	N Area Injection	200 Area Crib
Sensitivities and uncertainties	Some uncertainties exist in the data with regard to tritium plume concentration profiles; discharge levels will probably be somewhat lower than assumed for this study	Same as river discharge	Same as river discharge	Pipeline may be undersized if flow rates have to be increased beyond design capacity

ARAR - applicable or relevant and appropriate requirement
MCL - maximum contaminant level

Table 6-8 Cost Evaluation for Groundwater Extraction Options

Cost in Millions of 1993 Dollars	Extraction System	
	Five-Well System	Three-Well System
Capital Cost	1.53	1.01
Annual O&M Cost	0.03	0.02
Present Worth	1.77	1.17

O&M - operating and maintenance

Table 6-9 Cost Evaluation for Ion Exchange System

Cost in Millions of 1993 Dollars	Five-Well System	Three-Well System
Capital Cost	2.97	2.11
Annual O&M Cost	1.29	0.78
Present Worth	12.94	8.14

O&M - operating and maintenance

Table 6-10 Cost Evaluation for Reverse Osmosis System

Cost in Millions of 1993 Dollars	Five-Well System	Three-Well System
Capital Cost	2.26	1.58
Annual O&M Cost	0.83	0.50
Present Worth	8.70	5.45

O&M - operating and maintenance

Table 6-11 Cost Evaluation for River Disposal

Cost in Millions of 1993 Dollars	Five-Well System	Three-Well System
Capital Cost	0.06	0.05
Annual O&M Cost	<0.01	<0.01
Present Worth	0.07	0.06

O&M - operating and maintenance

Table 6-12 Cost Evaluation for N Area Crib Disposal

Cost in Millions of 1993 Dollars	Five-Well System	Three-Well System
Capital Cost	2.85	2.05
Annual O&M Cost	<0.01	<0.01
Present Worth	2.92	2.09

O&M - operating and maintenance

Table 6-13 Cost Evaluation for N Area Reinjection

Cost in Millions of 1993 Dollars	Five-Well System	Three-Well System
Capital Cost	1.13	0.85
Annual O&M Cost	<0.01	<0.01
Present Worth	1.20	0.89

O&M - operating and maintenance

Table 6-14 Cost Evaluation for 200 Area Crib Disposal

Cost in Millions of 1993 Dollars	Five-Well System	Three-Well System
Capital Cost	8.98	8.23
Annual O&M Cost	0.13	0.08
Present Worth	10.02	8.85

O&M - operating and maintenance

Table 6-15 Institutional Considerations Evaluation for Groundwater Extraction Options

Criteria	Evaluation	
	Five-Well System	Three-Well System
Ability to achieve removal action objectives	Achieves objectives; strontium-90 flux above 1,000 pCi/L is potentially completely eliminated	Achieves objectives; strontium-90 flux is restricted to a lesser extent than five-well system
Regulatory concerns about the technology	Concern should be low since technology is well proven for containment	Same as five-well system
Permitting requirements	None required	None required
Safety	Meets ALARA with engineering controls applied	Same as five-well system
Timeliness	Meets requirements	Meets requirements

ALARA - as low as reasonable achievable

Table 6-16 Institutional Considerations Evaluation for Groundwater Treatment Options

Criteria	Evaluation	
	Ion Exchange	**Reverse Osmosis**
Ability to achieve removal action objectives	Uncertain; treatability studies required	Uncertain; treatability studies required
Regulatory concerns about the technology	Concern should be low since technology is well proven	Same as ion exchange
Permitting requirements	None required	None required
Safety	Meets ALARA	Meets ALARA
Timeliness	Meets requirements	Meets requirements

ALARA - as low as reasonably achievable

Table 6-17 Institutional Considerations Evaluation for Treated Water Disposal Options

Criteria	Evaluation			
	River Discharge	**N Area Crib**	**N Area Injection**	**200 Area Crib**
Ability to achieve removal action objectives	Achieves removal objectives for all contaminants except tritium	Same as river discharge option	Same as river discharge option	Achieves all objectives
Regulatory concerns about the technology	Tritium above drinking water standards	Same as river discharge but soil column acts as buffer	Same as river discharge; state not likely to favor injection	Same as river discharge but soil column acts as buffer
Permitting requirements	NPDES	WAC 173-216	WAC 173-218	WAC 173-216
Safety	Meets ALARA	Meets ALARA	Meets ALARA	Meets ALARA
Timeliness	Meets requirements	Meets requirements	Meets requirements	Meets requirements

NPDES - National Pollutants Discharge Elimination System
ALARA - as low as reasonably achievable
WAC - Washington Administrative Code

Table 6-18 Environmental Impacts Evaluation for Groundwater Extraction Options

Criteria	Evaluation	
	Five-well System	Three-well System
Environmental impacts on: Topography and surface drainage	No impact	No impact
Geology	No impact	No impact
Soils	No impact	No impact
Surface water hydrology and quality	Some surface water will flow into the pumping wells; surface water quality will increase through removal of strontium-90	Same as five-well system but with a lesser increase in surface water quality
Groundwater hydrology and quality	Hydrology will be impacted by increasing gradients in the capture zone; flow of contamination toward the well will be accelerated due to the pumping effect	Same as five-well system but to a lesser extent
Meteorology and air quality	No impact	No impact
Biological resources	No impact	No impact
Cultural resources	No impact	No impact
Land and water use	Water use restrictions will continue; same as no action	Same as five-well system
Visual resources	No impact	No impact

Table 6-19 Environmental Impacts Evaluation for Treated Water Disposal Options (Page 1 of 2)

Criteria	Evaluation			
	River Discharge	N Area Crib	N Area Injection	200 Area Crib
Environmental impacts on: Topography and surface drainage	No impact	Potential slight topography changes from crib excavation	No impact	Potential slight topography changes from crib excavation
Geology	No impact	No impact	No impact	No impact
Soils	No impact	Tritium will increase in disposal crib soils and underlying groundwater aquifer sediments	Contamination of currently clean aquifer sediments with tritium	Same as N Area crib
Surface water hydrology and quality	Discharge of tritiated water into the river could impact the surface water in the immediate vicinity	Tritiated water could impact near-shore surface water quality	Same as N Area crib	Elimination of contamination impact to river
Groundwater hydrology and quality	No impact	Local groundwater hydrology impacted	Same as N Area crib	200 Area groundwater hydrology impacted;
Meteorology and air quality	No impact	No impact	No impact	No impact
Biological resources	Minimal impact in immediate vicinity of discharge point	No impact except at river flow interface	Same as N Area crib	No impact

Table 6-19 Environmental Impacts Evaluation for Treated Water Disposal Options (Page 2 of 2)

Criteria	Evaluation			
	River Discharge	**N Area Crib**	**N Area Injection**	**200 Area Crib**
Cultural resources	No impact	Minimal or no impact	Minimal or no impact	Minimal or no impact
Land and water use	Water use restricted at discharge point	Same as river discharge	Same as river discharge	Same as river discharge
Visual resources	No impact	No impact	No impact	No impact

Table 6-20 Technical Feasibility Evaluation for Slurry Wall Alternative

Criteria	Evaluation
Ability to comply with ARAR	Uncertain; wall intersects most of the > 42 pCi/L contour; however, the effect at the ends of the wall and the effects of the contaminated aquifer sediments between the wall and the river are not sufficiently characterized to accurately predict compliance with the proposed MCL.
Effectiveness in reducing toxicity, mobility, or volume of contamination	Restricts the flow of water containing both strontium-90 and tritium although tritiated water will flow around the wall because it is not retarded by the soil
Demonstrated performance and reliability under similar conditions	Slurry walls have been used effectively for containment actions at RCRA/CERCLA sites throughout the country
Useful life	Exceeds requirements
Constructability	Readily constructable but rocky soils will make construction more difficult
Operation and maintenance requirements	Vegetative cap may be required to prevent dehydration of bentonite and restore area to a more natural setting; continued spring and groundwater monitoring after installation
Environmental effects on performance	Natural flow of groundwater has the potential to deteriorate the performance of the barrier over time
Sensitivities and uncertainties	Soil testing is needed to provide data on design of slurry formulations including compatibility with the injection system equipment

MCL - maximum contaminant level
RCRA - Resource Conservation and Recovery Act
CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act
ARAR - applicable or relevant and appropriate requirements

Table 6-21 Cost Evaluation for Slurry Wall Alternative

104-ft Deep Wall Placed 100 ft from the River	
Cost in Millions of 1993 Dollars	**Deep Soil Mixing**
Capital Cost	10.01
Annual O&M Cost	0
Present Worth	10.01

50-ft Deep Wall Placed 50 ft from the River	
Cost in Millions of 1993 Dollars	**Deep Soil Mixing**
Capital Cost	6.16
Annual O&M Cost	0
Present Worth	6.16

O&M - operating and maintenance

Table 6-22 Institutional Considerations Evaluation for Slurry Wall Alternative

Criteria	Evaluation
Ability to achieve removal action objectives	Strontium-90 flux is restricted; achieves objectives
Regulatory concerns about the technology	Concern should be low since technology is well proven
Permitting requirements	None required
Safety	Meets ALARA
Timeliness	Meets requirements

ALARA - as low as reasonably achievable

Table 6-23 Environmental Impacts Evaluation for Slurry Wall Alternative

Criteria	Evaluation
Environmental impacts on: Topography and surface drainage	No impact
Geology	No impact
Soils	Reduced contamination in riverbank soils
Surface water hydrology and quality	Improved surface water quality in the long-term as a result of restricting flow of contaminants into the river; near-term effects are uncertain because of the sediments between the wall and the river
Groundwater hydrology and quality	Groundwater hydrology in the N Area is altered; the groundwater gradient behind the wall is decreased; the gradient at the ends of the wall is increased; the wall results in approximately 1.6 ft (0.5 m) rise in water level on the upgradient side of the wall, based on modeling results
Meteorology and air quality	No impact
Biological resources	Less threat to riparian and aquatic biota
Cultural resources	No impact
Land and water use	No impact.
Visual resources	No impact

Table 6-24 Technical Feasibility Evaluation for Hydraulic Control Alternative

Criteria	Evaluation
Ability to comply with ARAR	Flow of contamination to river is restricted but alternative does not meet chemical-specific ARAR
Effectiveness in reducing toxicity, mobility, or volume of contamination	Restricts the flow of water containing strontium-90 and tritium
Demonstrated performance and reliability under similar conditions	Hydraulic control has been used effectively for containment actions at RCRA/CERCLA sites
Useful life	Meets requirements
Constructability	Readily constructable
Operation and maintenance requirements	System is not complex and easy to operate; some maintenance required for pumps
Environmental effects on performance	Changing hydrologic conditions could affect system performance
Sensitivities and uncertainties	Uncertainties in hydrologic properties and heterogeneities of the flow system

ARAR - applicable or relevant and appropriate requirements
RCRA - Resource Conservation and Recovery Act
CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act

Table 6-25 Cost Evaluation for Hydraulic Control Alternative

Cost in Millions of 1993 Dollars	Hydraulic Control System
Capital Cost	2.30
Annual O&M Cost	0.07
Present Worth	2.85

O&M - operating and maintenance

Table 6-26 Institutional Considerations Evaluation for Hydraulic Control Alternative

Criteria	Evaluation
Ability to achieve removal action objectives	Strontium-90 flux is restricted; achieves objectives
Regulatory concerns about the technology	Concern should be low since technology is proven in the field
Permitting requirements	None required
Safety	No contaminated water is pumped
Timeliness	Meets requirements

Table 6-27 Environmental Impacts Evaluation for Hydraulic Control Alternative

Criteria	Evaluation
Environmental impacts on: Topography and surface drainage	No impact
Geology	No impact
Soils	Reduced contamination in riverbank soils
Surface water hydrology and quality	Improved surface water quality as a result of restricting flow of contaminants into the river
Groundwater hydrology and quality	Groundwater hydrology in the N Area is altered, groundwater quality remains the same
Meteorology and air quality	No impact
Biological resources	Less threat to riparian and aquatic biota as a result of reducing contamination flux to the river
Cultural resources	No impact
Land and water use	No impact
Visual resources	Minimal impact; wells are visible but not intrusive

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7.0 COMPARATIVE ANALYSIS OF REMOVAL ACTION ALTERNATIVES

This section provides comparisons of the four alternatives evaluated in Section 6.0. Each alternative is compared against the others in relation to the evaluation criteria. Cost-benefits of the alternatives are compared based on correlation of cost with the estimated percentages of strontium-90 reductions achieved by each alternative.

7.1 ALTERNATIVE COMPARISONS

Comparisons of the alternatives based on the evaluation criteria are summarized in the subsections below.

7.1.1 Technical Feasibility

7.1.1.1 Ability to Comply with ARAR. Ability to comply with the proposed MCL for strontium-90 is uncertain for all the alternatives. All alternatives, except for no action, reduce the flux of contamination to the river to some degree. Based on existing modeling, the 5-well pump and treat results in the greatest reduction of flux with the 3-well and slurry wall having lower flux reductions which are roughly equal. The hydraulic control reduces the strontium-90 flux the least. These relationships are based on the flux reduction at 33 ft (10 m) from the river across a 2,800-ft (853-m) zone (see further discussion in Section 7.2). The flux at either end of this flux line has not been quantified by the modeling efforts. In addition, the location of the wall significantly affects the effectiveness at reducing the flux. Additional modeling to quantify the flux across the entire model and the optimization of the slurry wall and pumping well placement are needed to compare all the alternatives on a more equitable basis.

None of the alternatives meet the proposed tritium MCL for surface or groundwater discharge. While the 200 Area crib disposal option for pump and treat prevents tritium discharge to surface water above the MCL, discharging the water to groundwater at the 200 Area may require an ARAR waiver. The slurry wall potentially reduces the level of tritium reaching the river through the creation of a longer flow path. It is also possible that the pump and treat option may result in concentrations below the proposed MCL because of dilution by inflowng river water.

Location-specific and action-specific ARAR are generally met by all the alternatives. Some additional analysis of the wetland and Wild and Scenic Rivers Act issues is warranted in the design phase.

7.1.1.2 Effectiveness in Reducing Toxicity, Mobility, or Volume of Contamination. All alternatives except no action reduce the flux of strontium-90 to the river, but to a different extent depending upon the technology or process option. However, all alternatives, except no action, meet the removal action objective of eliminating or substantially reducing the flux of strontium-90 to the river.

The pump and treat options reduce both the mobility and volume of contamination by the removal of the strontium-90 from the groundwater stream. The 5-well system performs better than the 3-well system because it intercepts more of the plume. The slurry wall and hydraulic control alternatives reduce the mobility of the contaminants.

7.1.1.3 Demonstrated Performance and Reliability Under Similar Conditions. All technologies have been proven in field applications that are similar to the proposed application. Reliability of all removal action technologies is considered good, although the vertical barrier is the least complex and therefore the most reliable. The pump and treat alternative is the most complex because it involves extraction, treatment, maintenance, and disposal operations; therefore, reliability may be less than the other alternatives.

7.1.1.4 Useful Life. All alternatives meet the requirement of this ERA for a 10-year useful life. All the alternatives can be easily incorporated into future remedial actions for the operable unit.

7.1.1.5 Constructability. All alternative systems are readily constructable. Constructability of the vertical barrier is less certain than the others because of Hanford's rocky soils.

7.1.1.6 O&M Requirements. The pump and treat alternative requires the most O&M; the vertical barrier requires the least. Hydraulic control O&M requirements are low. For pump and treat, river disposal requires the least O&M, while 200 Area crib disposal requires the most.

7.1.1.7 Environmental Effects on Performance. None of the alternatives are sensitive to environmental effects such as weather or terrain. The pump and treat alternative requires protection from freezing; however, this is addressed by enclosing the treatment system in a heated building.

7.1.1.8 Sensitivities and Uncertainties. With the exception of the no action alternative, all the alternatives are feasible for application at N Springs. However, because none of the technologies has been applied at Hanford Site conditions, the technical feasibility has some uncertainties. For the slurry wall, the uncertainty of installation in the rocky soils is a concern. Field testing is recommended to assess the impacts of the gravels and boulders on the deep soil mixing slurry wall and to optimize slurry formulations. For pump and treat, uncertainties lie in the ability to treat the groundwater to meet discharge levels. Treatability testing is necessary before performance factors can be confidently assessed. Both ion exchange and reverse osmosis treatment options generate substantial volumes of secondary waste. In the case of ion exchange, the volume of solid zeolite resins requiring disposal as low-level waste depends upon the media loading capacity. This loading capacity is sensitive to influent concentrations, including content of noncontaminants, such as calcium and nonradioactive strontium, and to the decontamination factors required. Disposal of tritiated water is another uncertainty associated with the pump and treat alternative, both in terms of institutional considerations and cost. The hydraulic control option has uncertainties associated with efficiency and the potential for increased contamination of clean areas.

Capture effectiveness for the pump and treat will be influenced by hydraulic conductivity. If conductivities are higher than modeled, higher pumping rates would be required for effective capture which directly affects treatment system size and design. Heterogeneities in the aquifer sediments could also produce adverse effects on contaminant capture. The slurry wall would be affected by the possible irregular contact between the aquifer and underlying confining layer.

Hydraulic control is very sensitive to hydrologic properties and aquifer heterogeneities. If hydraulic conductivities are higher than modeled, pumping rates would have to be increased to maintain the same effect on downgradient water levels. However, higher pumping rates present a greater risk of drawing contamination further upgradient. Aquifer heterogeneities in the form of flow channels could also result in upgradient flow of contamination and lower effectiveness in controlling gradients in the intended portion of the plume.

7.1.2 Cost Considerations

The present worth of the alternatives, including options within the pump and treat alternative, are compared in Table 7-1. As indicated in the table, present worth (excluding no action) ranges from a low of about $2.74 million for the hydraulic control alternative to a high of over $22 million for a five-well pump and treat using ion exchange treatment and 200 Area crib disposal.

The cost analysis indicates that among the pump and treat options, cost is most sensitive to the system size in terms of flowrate from the wells, followed by the type of water disposal, and finally to the type of treatment. Cost differentials between a three-well and five-well system are on the order of $3-6 million. Cost differentials between river disposal and 200 Area crib disposal are on the order of $8 to $10 million. Cost differentials between reverse osmosis and ion exchange treatment were estimated to be $2 to $4 million based on vendor information. However, the cost differences between reverse osmosis and ion exchange treatment are uncertain. It is possible that reverse osmosis is more costly than ion exchange, but costs cannot be refined further without treatability studies. Costs for extraction wells are fairly certain because they are based on well-defined, historical drilling costs at Hanford. Costs for treated water disposal carry moderate uncertainties in that, even though the systems are straightforward, costs for pipelines and cribs are subject to further refinement with greater design definition. Additional uncertainties include disposal costs and operating downtime. The disposal costs for secondary wastes for the ion exchange system are significant. Any reduction in the disposal costs has a corresponding reduction in the present worth. However, at this time, no other disposal options are available. Potential disposal to the ERDF can be considered in the future, but at this time the costs are not available. The operating costs are highly dependant on downtime and on the ability to conduct the treatment as a CERCLA cleanup. If the treatment system is required to be designed, constructed, and operated as a nuclear facility, then the costs would be increased significantly.

Costs for slurry wall installation are based solely on estimates provided by vendors, although two vendors provided estimates that were on the same order of magnitude. Both vendors state that field testing is required to determine optimum slurry mixes. Costs for the slurry wall will likely change as site-specific design is performed. The major cost uncertainties associated with slurry wall installation are those that relate to unexpected field conditions, (e.g., encountering large boulders [>3 ft diameter]) that interfere with augering. Placement of the wall closer to the river would result in significant cost savings because the wall depth would be reduced approximately 50%. However, placing the wall closer to the river requires a wetlands assessment. This issue can be more fully addressed in the design phase of the ERA.

Costs for hydraulic control are fairly certain because they are based primarily on historical well installation costs. There is more uncertainty in the costs of installing a water pipeline to the river.

7.1.3 Institutional Considerations

7.1.3.1 Ability to Achieve Removal Action Objectives. All alternatives, except no action, meet the removal action objective of eliminating or substantially reducing strontium-90 flux to the river. The five-well pump and treat and the vertical barrier are potentially more effective in reducing the flux relative to the other alternatives, depending on the placement of the slurry wall.

7.1.3.2 Regulatory Concerns about the Technology. All technologies are proven for site remediation and thus should not raise concern among the regulators.

7.1.3.3 Permitting Requirements. The pump and treat alternative will require that substantive requirements of permitting regulations be met for disposal of the treated water. For example, river discharge requires meeting NPDES requirements. The vertical barrier and hydraulic control alternatives should not trigger any permit requirements; however, a wetlands assessment may be warranted depending on the slurry wall location.

7.1.3.4 Safety. All alternatives will meet ALARA requirements through application of standard control for construction and operation. Pump and treat will require appropriate controls for handling treatment residues. Some shielding may be required on vessels where strontium-90 is concentrated, although shielding will be modest because there are no significant concentrations of gamma emitters.

7.1.3.5 Timeliness. All alternatives can be implemented within a time frame that meets ERA objectives. Pump and treat will require treatability studies prior to design of treatment systems. The slurry wall will require field testing of slurry formulations and a demonstration of implementability in Hanford soils. Hydraulic control can be implemented in the shortest time frame.

7.1.4 Environmental Impacts

All alternatives, except no action, will impact the river positively by reducing the flux of strontium-90 in the riverbank springs. This will benefit riparian biota and downstream water users. All alternatives, except for no action, will alter groundwater hydrology in the area of the plume; however, this will not cause impacts to human health or the environment. All alternatives will continue to require land use restrictions and restrictions on use of water from the contaminated portions of the aquifer.

7.2 COST-BENEFIT ANALYSIS

Cost-benefit of each alternative is analyzed by correlating present worth costs to estimated reductions in strontium-90 flux as a percentage of no action (benefit). The result of this analysis is shown graphically in Figure 7-1. In this figure, the estimated percent reduction in strontium-90 flux to the river is plotted as the abscissa against the present worth cost as the ordinate. The percent reduction is derived from the modeling results. The flux of strontium-90 was modeled for the no action, three-well and five-well pump and treat, and slurry wall alternative systems being placed 100 ft (30 m) from the river. The flux was measured along a 2,800-ft (853-m) flux line located parallel to and 33 ft (10 m) from the river. The total curies of strontium-90 passing the flux line for each alternative are compared to the total for the no action scenario. These percentages are then plotted against the costs for the individual alternatives to graphically represent the cost-benefit of each alternative.

The figure is representative of the existing modeling only. One of the uncertainties associated with the slurry wall is the placement distance of the wall from the river. If the wall is placed 100 ft (30 m) from the river, the flux reduction is nearly 100% at the wall, but is only about 71% at the flux line 33 ft (10 m) from the river. This is because the strontium-90 remaining in the area between the wall and the river continues to flush into the river and because of the small quantity of strontium-90 in the water flowing around the ends of the wall. If the slurry wall is placed at the river, the flux reduction is nearly 100%. Any placement of the wall between the river and 100 ft (30 m) would result in a flux reduction between 71% and 100%. Placement cannot be optimized from the existing modeling.

A major benefit of moving the wall closer to the river is the significant reduction in cost. By placing the wall 50 ft (15 m) from the river the depth of the wall is reduced by one-half. Cost of the wall is reduced from $10 million to about $6 million (assuming a scaling of depth of the wall using a 0.7 capital cost scaling factor). Placement of the wall 50 ft (15 m) from the river would require a wetlands assessment.

The hydraulic control option was modeled only with the FLOWPATH model and not with PORFLO-3; therefore a similar comparison cannot be made with this option. The percent reduction value for the hydraulic control alternative is based on capture zone analysis of the groundwater flux to the river.

Note that in the figure the no action and hydraulic control alternatives plot as a single point. However, the slurry wall and pump and treat alternative options plot as a range. Ranges are shown for the three-well and five-well extraction systems. The cost range for each of the pumping options reflects the cost differences in the treated water disposal options and in the treatment options. The figure reflects those parameters which could be quantified for this ERA. However, uncertainties may lie in both the costs and effectiveness of the alternatives. The effectiveness of the slurry wall is related to placement. Likewise the pump and treat costs may be slightly higher or lower. However, these uncertainties cannot be quantified with existing data. The information shown on the figure represents the modeling results, professional judgement, and current data available for the N Spring area. Further analysis at this stage would require unsupportable assumptions which would not decrease the level of uncertainty.

Based on analysis of the cost-benefit relationship of Figure 7-1, several generalizations and conclusions can be reached. These are discussed as follows:

- Additional information is needed prior to implementation of a preferred alternative.

- For the pump and treat options, river disposal appears to be the best choice among all treated water disposal options, especially considering the proposed MCL for tritium. Current tritium levels are very close to this proposed value. The 100 N Area reinjection and the 100 N Area crib disposal option do not offer significant additional benefit for handling tritium but result in substantially greater costs. Further, the benefit of crib disposal and reinjection are considered negative, since either may result in contamination of additional aquifer sediments or mobilization of resident contaminants. Disposal at a 200 Area crib offers better protection of the river but results in further aquifer sediment contamination and greater expense.

- Based on existing modeling, the five-well system appears to offer the highest level of flux reduction. The slurry wall may provide equivalent effectiveness if properly placed; however, additional analysis is necessary to determine this effectiveness.

- Secondary waste considerations, such as the tritiated water, reverse osmosis reject stream, and spent ion exchange media, are a drawback for the pump and treat alternatives. The slurry wall and hydraulic control are not constrained by these secondary waste issues.

- For the slurry wall and hydraulic control alternatives, the potential to contaminate clean aquifer material exists.

- Hydraulic control offers the lowest cost; however, the uncertainties associated with the hydraulic control alternative are greater than the other alternatives. The modeling shows that upgradient hydraulic control could achieve approximately a 50% reduction in strontium-90 flux without drawing the contamination into clean areas. This reduction could be worse if hydraulic conductivity is higher or if significant flow channels are present.

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Figure 7-1 Cost Benefit Analysis of Alternatives

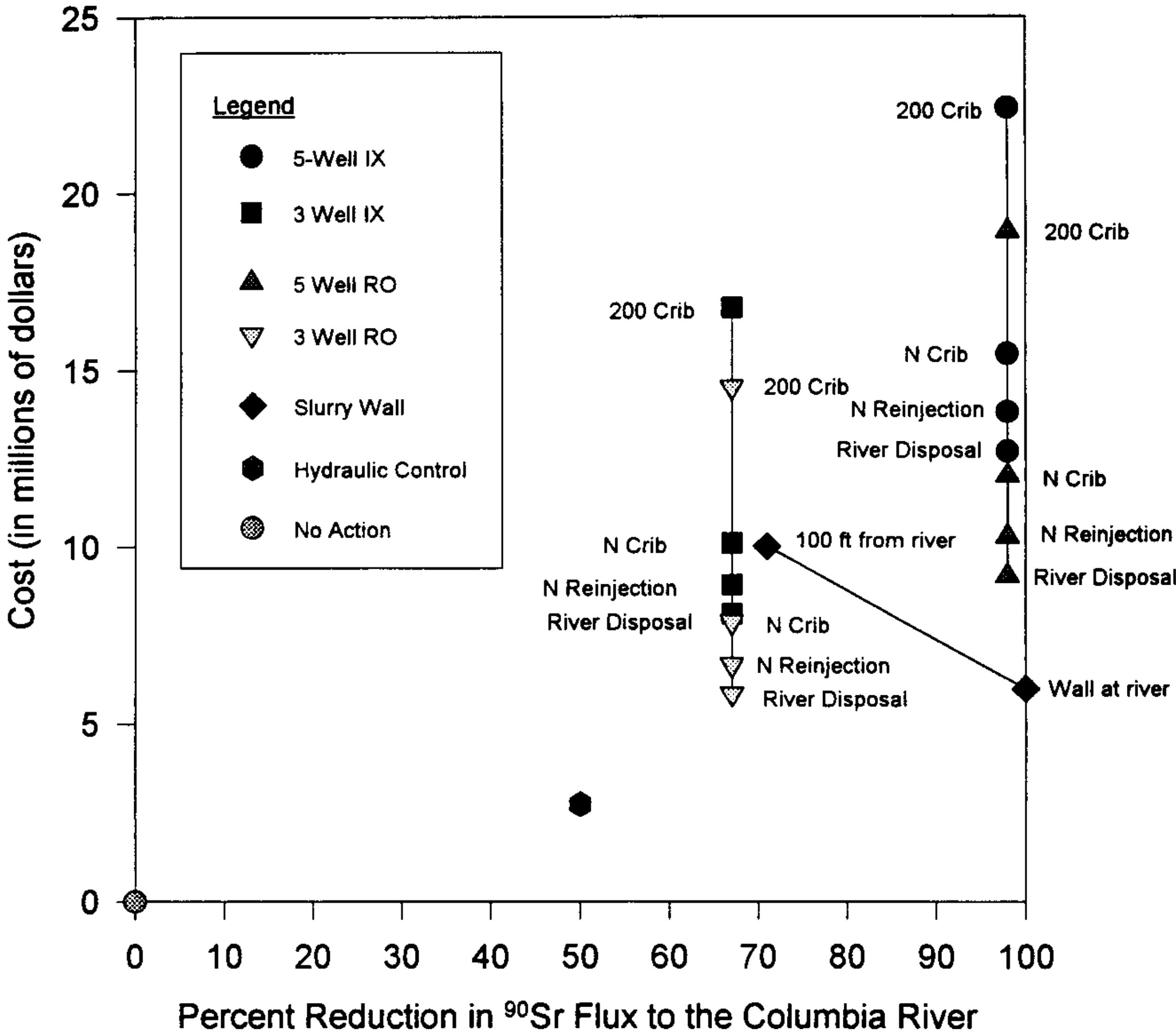

Table 7-1 Cost Comparison of Alternatives

Alternative Present Worth Comparisons (In Millions of $)		
Alternative 1	**No Action** $0	
Alternative 2	**Five Well**	**Three Well**
Ion Exchange:		
River Disposal	$11.12	$8.06
N Area Crib	$13.94	$10.09
N Reinjection	$11.15	$8.07
200 Area Crib	$11.92	$8.53
Reverse Osmosis:		
River Disposal	$5.34	$5.81
N Area Crib	$5.38	$5.83
N Reinjection	$5.38	$5.83
200 Area Crib	$6.14	$6.29
Alternative 3	**Slurry Wall**	
100 ft from river	$10.01	
At the river	$6.37	
Alternative 4	**Hydraulic Control** $0.44	

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8.0 PREFERRED ALTERNATIVE

The preferred alternative should provide a high degree of protectiveness balanced with acceptable risks and reasonable costs. However, as a result of the additional analysis performed in response to regulatory comments, it is now concluded that a preferred alternative cannot be confidently recommended in view of the technical and cost uncertainties of both alternatives. Therefore, both the slurry wall and the pump and treat alternatives are recommended as preferred alternatives. Additional information may be needed prior to implementing a single preferred action. The following activities are proposed to gather this information:

- Time consistent groundwater and spring sampling - All wells associated with the N Springs area and the strontium-90 plume, including the wells at the springs, should be sampled at the same time to allow construction of representative contaminant plume maps. This information will be used to construct the groundwater model.

- Additional groundwater flow and contaminant transport modeling for the alternatives - The model will be constructed specifically for the evaluation of these alternatives using current N Springs area conditions. The model will be used to evaluate performance of the alternatives including hydraulic control to optimize elements of each alternative, such as wall length and placement, well spacing, and well pumping rates, and to determine remediation time frames.

- Subsurface characterization - Two borings will be drilled to define the confining layer depth and thickness. Sediment samples from the aquifer will be collected to determine aquifer physical parameters including strontium-90 sorption characteristics.

- Slurry wall implementability test - A test panel using the deep soil mixture equipment will be constructed in a clean zone in the 100 N Area. Slurry formulations consistent with the N Springs area water and soils will be developed. Following placement of the test panel, the panel will be drilled to determine if the panel meets permeability criteria.

- Treatability studies for ion exchange and reverse osmosis treatment systems - A bench-scale treatability study will be conducted for the ion exchange treatment system. Information will be generated (in coordination with other treatability tests being conducted on-site) on appropriate ion exchange media, media loading, waste generation, and costs. A pilot-scale reverse osmosis treatability test will be conducted in the field to determine an acceptable membrane, membrane loading, waste generation, waste water treatment, and cost.

- Wetlands regulatory review/assessment - A regulatory review will be conducted to determine the requirements needed to conduct the ERA near the river. Wetlands, floodplain, and Wild and Scenic Rivers Act regulations will be reviewed to identify requirements; appropriate federal and state agencies will be contacted if necessary. If warranted, a wetlands assessment will be conducted prior to alternative implementation. This issue directly affects the location, size, effectiveness, and cost of the slurry wall.

- Endangered vegetation study - A study of endangered species located at the N Springs area will be conducted to identify potential impacts.

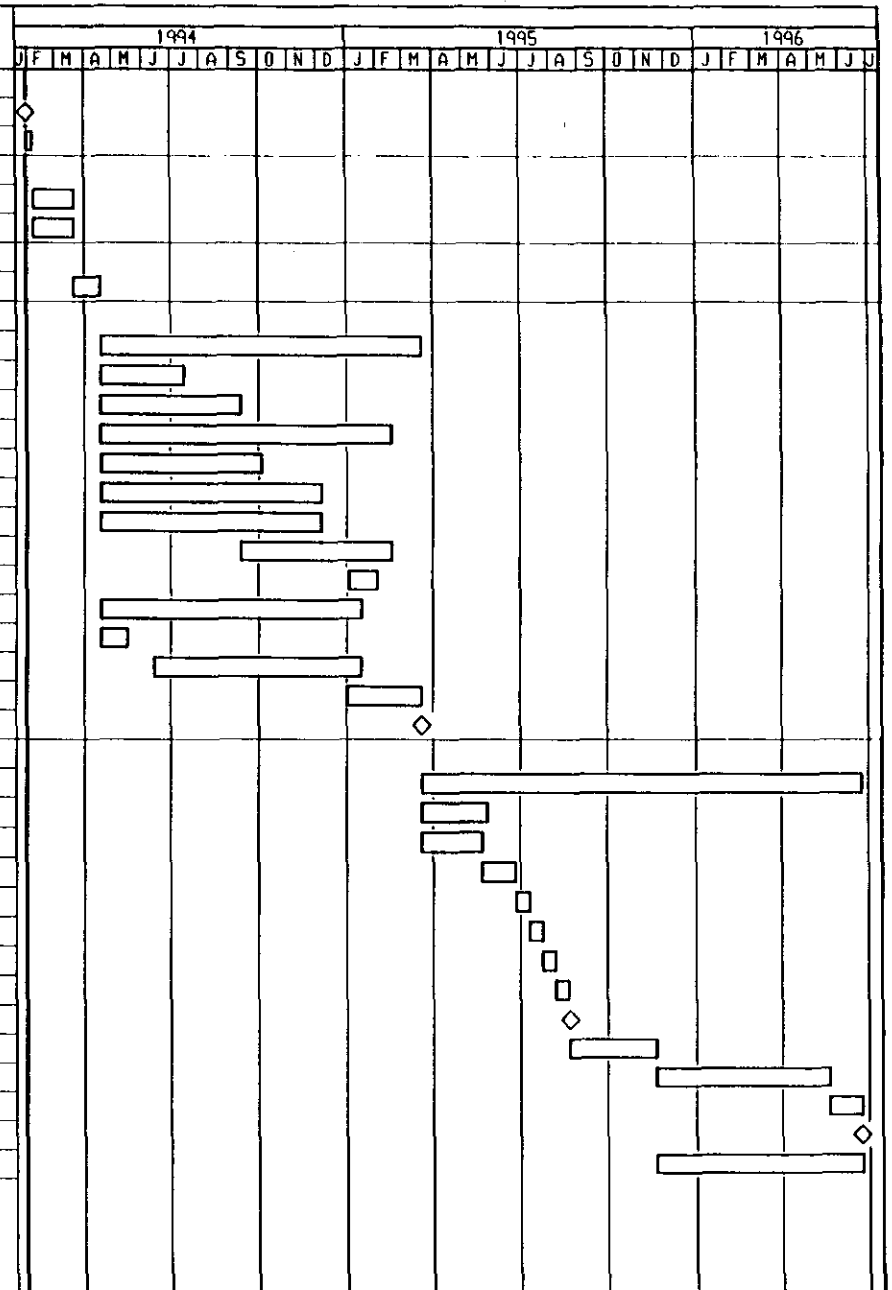
- Additional analysis and refinement of costs - The cost estimates will be refined based on the additional information gathered in the other activities.

The information gathered from the above activities will be used to implement the preferred alternative. This preferred alternative will continue through the design phase and ultimately be implemented.

9.0 SCHEDULE

Figure 9-1 is a schedule for the modeling, characterization, and testing program proposed for the design phase of the ERA. In addition, the schedule in Figure 9-1 includes the construction and implementation phases of the ERA.

ACTIVITY DESCRIPTION	ORIG DUR	EARLY START	EARLY FINISH
Deliver to Regulators	0	31JAN94	
Regulator Review	7	31JAN94	6FEB94
ERA Proposal	43	7FEB94	21MAR94
Public Comment	43	7FEB94	21MAR94
Prepare & Issue Action Memorandum	29	21MAR94	18APR94
ERA Preliminary Design & Testing	337	18APR94	20MAR95
Endangered Vegetation Study	89	18APR94	15JUL94
Boreholes	148	18APR94	12SEP94
Slurry Well Implementability Test	306	18APR94	17FEB95
Time Consistent GW & Spring Sampling	169	18APR94	3OCT94
Ion Exchange Treatability Studies	232	18APR94	5DEC94
Reverse Osmosis Treatability Test	232	18APR94	5DEC94
GW Flow & Contaminant Modeling	159	12SEP94	17FEB95
Revise Cost Estimate	31	3JAN95	2FEB95
Floodplain/Wetland Analysis	274	18APR94	16JAN95
Review	29	18APR94	16MAY94
Analysis	218	13JUN94	16JAN95
Preliminary Design Report	79	1JAN95	20MAR95
Document to Regulators	0		20MAR95
Implementation (Design/Build/Operate)	463	20MAR95	24JUN96
Commerce Buisness Daily	69	20MAR95	27MAY95
Prepare Specifications	64	20MAR95	22MAY95
Solitation	36	22MAY95	26JUN95
Proposed Evaluation	15	26JUN95	10JUL95
Vender Discussion	15	10JUL95	24JUL95
Best and Final	15	24JUL95	7AUG95
Final Evaluation	15	7AUG95	21AUG95
Award	0		21AUG95
Design	92	21AUG95	20NOV95
Mobilize and Construct	183	20NOV95	20MAY96
Testing	36	20MAY96	24JUN96
Operate/Operational Monitoring	0	24JUN96	
Site Preparation	218	20NOV95	24JUN96



Plot Date 24JAN94
Data Date 31JAN94
Project Start 31JAN94
Project Finish 30SEP96

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N SPRINGS

BASELINE SCHEDULE

BASELINE SCHEDULE

Date	Revision	Checked	Approved

Figure 9-1 N Springs ERA Schedule

10.0 REFERENCES

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APPENDIX A

COST ESTIMATES

CONTENTS

Cost Estimate Assumptions and Estimating Sources
N Springs ERA

Assumptions:

1. Westinghouse in-house crafts install all individual pieces such as pumps, tanks, mixers, and pipe; perform site preparation; use WHC labor rates ($53.64/hr from WHC Program Office)

2. Subcontractors install all skid-mounted packages and construct large items such as the transfer pipe to the 200 Area; also assumes that subcontractors erect buildings, install concrete floors and foundations, and perform all trenching/backfilling ($95.87/hr from WHC Program Office)

Sources:

1. Based on actual costs of cable tool drilling of monitoring wells by Kaiser Engineers; per foot cost from WHC Program Office; contact K. Popham

2. Richardson Cost Engineering Services, Richardson Rapid System, Process Plant Construction Estimating Standards

3. Cost quotation from Familian Northwest, Inc. (Goulds Pumps); Portland, Oregon; contact Randy Mather (503-283-3333)

4. Cost quotation from Corr Tech, Inc; Houston Texas; contact Brian Mause (713-674-7242)

5. Vatavuk, William M., *Estimating Costs of Air Pollution Control*, Lewis Publishers, 1990

6. Electric power rate from Benton County PUD; commercial rate for usage in the range of 2500-17500 kw

7. Cost quotation from Babcock and Wilcox; contact Dr. Billy Bingham (804-385-3267)

Cost Estimate Assumptions and Estimating Sources
N Springs ERA

Sources (Continued)

8. WHC LLW disposal cost; contact Frank Gustavson

9. Cost quotation from Polymetrics, Inc.; contact Les Bell (719-570-7507)

10. Cost quotation from Licon, Inc.; contact Edgar Steindal (904-434-5088)

11. Cost quotation from WHC stores

12. Based on calculation brief by IT Corp.

13. Best professional judgement assumption; contact Joe Alvarez, IT Corp. (303-694-0044)

14. Based on KEH cost estimate for Project C018H crib; contact Frank Gustavson

15. Based on actual costs of Odex drilling of monitoring wells in uncontaminated areas by Kaiser Engineers; per foot cost from WHC Program Office; contact K. Popham

16. Based on cost quotation from Millgard Environmental Corp.; contact Jeff Jacobs (313-261-9760)

Alternative Present Worth Comparisons
(In Millions of $)

Alternative 1	**No Action**	
	$0	
Alternative 2	**Five Well**	**Three Well**
Ion Exchange:		
River Disposal	$12.69	$8.10
N Area Crib	$15.47	$10.09
N Reinjection	$13.81	$8.92
200 Area Crib	$22.43	$16.77
Reverse Osmosis:		
River Disposal	$9.18	$5.85
N Area Crib	$12.01	$7.88
N Reinjection	$10.29	$6.68
200 Area Crib	$18.91	$14.52
Alternative 3	**Slurry Wall**	
	$10.01	
Alternative 4	**Hydraulic Control**	
	$2.74	

Alternative Capital
Cost Comparisons
(In Millions of $)

Alternative 1	**No Action**	
	$0	
Alternative 2	**Five Well**	**Three Well**
Ion Exchange:		
River Disposal	$4.56	$3.17
N Area Crib	$7.35	$5.17
N Reinjection	$5.63	$3.97
200 Area Crib	$13.49	$11.35
Reverse Osmosis:		
River Disposal	$3.85	$2.64
N Area Crib	$6.63	$4.64
N Reinjection	$4.91	$3.44
200 Area Crib	$12.77	$10.83
Alternative 3	**Slurry Wall**	
	$10.01	
Alternative 4	**Hydraulic Control**	
	$2.30	

Alternative O&M
Cost Comparisons
(In Millions of $)

Alternative 1	**No Action**	
	$0	
Alternative 2	**Five Well**	**Three Well**
Ion Exchange:		
River Disposal	$1.32	$0.80
N Area Crib	$1.33	$0.81
N Reinjection	$1.33	$0.81
200 Area Crib	$1.46	$0.88
Reverse Osmosis:		
River Disposal	$0.87	$0.52
N Area Crib	$0.88	$0.53
N Reinjection	$0.88	$0.53
200 Area Crib	$1.00	$0.60
Alternative 3	**Slurry Wall**	
	$0.00	
Alternative 4	**Hydraulic Control**	
	$0.07	

Alternative 2
Pump and Treat - Extraction System

	Five Well System	Three Well System
Capital Cost:		
Wells	$793,936	$476,362
Pumps	$16,299	$9,779
Transfer Piping	$161,989	$155,253
Subtotal	$972,224	$641,394
Engineering @ 10%	$97,222	$64,139
Project Management @11%	$106,945	$70,553
Subtotal	$1,176,391	$776,087
Contingency @30%	$352,917	$232,826
Total Capital Cost	**$1,529,308**	**$1,008,913**
O&M Cost: (Annual)		
Operating Labor	*	*
Maintenance	$29,167	$19,242
Utilities	$2,083	$1,086
Total O&M Cost	**$31,250**	**$20,328**
Present Worth	**$1,721,326**	**$1,133,820**

*Included in treatment plant

Pump and Treat

System Module: Groundwater Extraction

Option: Five Well System

Cost Type	Component	Description	Quantity	Unit Cost	Total, $	Assumption	Source
Capital	Pumping Wells	6-inch diameter, 104 ft total depth, stainless steel, install by cable tool drilling; costs include all materials, mob/demob, drilling labor, logging, well development, waste disposal, equipment decon	520 ft	$1526.8/ft	793,936	--	1
	Pumps	5 hp, 100 gpm at 100 ft head, submersible, stainless steel; costs include materials and installation	5	--	16,299	1	3
	Transfer piping (transfer to treatment plant)	6-inch diameter, double wall PVC, buried below frost line; costs include pipe materials, valves, valve boxes and fittings, trenching, installation	2250 ft	--	147,263	1,2	4
	Piping leak detection	Materials and installation	--	10% of piping	14,726	--	5
O&M	Maintenance	System maintenance cost	--	3% of capital	29,167/yr	--	5
	Operating Labor	(*Include in treatement system costs)	--		*	--	--
	Elect. Power	Power for pumps; annual cost	62,000 kwh/yr	$0.0336/kwh	2,083/yr	--	6

Pump and Treat

System Module: Groundwater Extraction

Option: Three Well System

Cost Type	Component	Description	Quantity	Unit Cost	Total, $	Assumption	Source
Capital	Pumping Wells	6-inch diameter, 104 ft total depth, stainless steel, install by cable tool drilling; costs include all materials, mob/demob, drilling labor, logging, well development, waste disposal, equipment decon	312 ft	$1526.80/ft	476,362	--	1
	Pumps	5 hp, 100 gpm at 100 ft head, submersible, stainless steel; costs include materials and installation	3	--	9,779	1	3
	Transfer piping (transfer to treatment plant)	6-inch diameter, double wall PVC, buried below frost line; costs include pipe materials, valves, valve boxes and fittings, trenching, installation	2150 ft	--	141,139	1,2	4
	Leak detection	Materials and installation	--	10% of piping	14,114	--	5
O&M	Maintenance	System maintenance cost		3% of capital	19,242/ yr	--	5
	Operating labor	(*Include in treatment system costs)	--	--	*	--	--
	Elect. Power	Power for pumps; annual cost	32,300 kwh/yr	$0.0336/kwh	1,086/yr	--	6

Alternative 2
Pump and Treat - Treatment System
Ion Exchange

	Five Well System	Three Well System
Capital Cost: (Installed)		
Tanks and mixers	$21,962	$19,622
Feed pumps	$10,959	$9,755
IX package unit	$1,772,000	$1,239,500
IX pilot test by vendor	$45,000	$45,000
Site preparation	$8,429	$6,757
Treatment building	$28,323	$18,934
Building utilities and tie-ins	$2,823	$1,893
Subtotal	$1,889,496	$1,341,461
Engineering @ 10%	$188,950	$134,146
Project Management @11%	$207,845	$147,561
Subtotal	$2,286,290	$1,623,168
Contingency @30%	$685,887	$486,950
Total Capital Cost	**$2,972,177**	**$2,110,118**
O&M Cost: (Annual)		
Operating	$748,980	$449,445
Maintenance	$56,699	$40,233
Waste Dipsosal	$485,100	$291,060
Total O&M Cost	**$1,290,779**	**$780,738**
Present Worth	**$10,903,455**	**$6,907,415**

Pump and Treat

System Module: Treatment
Description: Ion Exchange - Five Well System

Cost Type	Component	Description	Quantity	Unit Cost	Total	Assumption	Source
Capital	Flow Equalization Tank	6000 gal, carbon steel/w epoxy lining, vertical	1	--	14,259	1	2
	Equalization Tank Mixer	6 hp, vertical/impeller type, carbon steel	1	--	7,703	1	2
	Influent Feed Pump	10 hp, 500 gpm at 40 ft head, centrifugal, carbon steel	2	--	10,959	1	2
	Ion Exchange Package Unit	Vendor engineered and constructed, zeolite, non-regenerative, skid-mounted, package unit, 300 gpm incluing pre- and post-filter units, ion exchange vessels, resin storage tank, resin load-in system, resin load-out	1	--	1,295,000	--	7
	IX Package Installation	Freight, install package, process piping; include materials and labor	1	--	477,000	2	7
	IX Pilot Test	Vendor pilot test	1	--	45,000	1	2
	Site Preparation	Clear and grub site, level and compact, 2000 ft2 area	1	--	8,429	1	2
	Treatment Building	1000 ft2 x 20 ft high metal building, (Butler-type); include concrete slab on grade, insulated with HVAC; include materials and installation	1	--	28,323	2	2
	Utilities and tie-ins	Building and process electrical, building plumbing and sewer/water tie-ins	1	10% of building cost	2,823	2	5
O&M	Operating	All materials and labor, excluding waste disposal	157.7 M gal/yr	$4.75/kgal	748,980/yr	--	7
	Maintenance	Materials and labor		3% of capital	56,699/yr	--	5
	Waste Disposal	Treatment residuals disposal as solid LLW; spent zeolite and filter wastes	7700 ft3/yr	$63/ft3	485,100/yr	--	8

Pump and Treat

	System Module: Treatment Description: Ion Exchange - Three Well System						
Cost Type	**Component**	**Description**	**Quantity**	**Unit Cost**	**Total**	**Assumption**	**Source**
Capital	Flow Equalization Tank	4000 gal, carbon steel/w epoxy lining, vertical	1	--	11,919	1	2
	Equalization Tank Mixer	4 hp, vertical/impeller type, carbon steel	1	--	7,703	1	2
	Influent Feed Pump	7.5 hp, 300 gpm at 40 ft head, centrifugal, carbon steel	2	--	9,755	1	2
	Ion Exchange Package Unit	Vendor engineered and constructed, zeolite, non-regenerative, skid-mounted, package unit, 180 gpm incluing pre- and post-filter units, ion exchange vessels, resin storage tank, resin load-in system, resin load-out	1	--	905,500	--	7
	IX Package Unit Installation	Freight, install package, process piping; include materials and labor	1	--	334,000	2	7
	IX Pilot Test	Vendor pilot test	1	--	45,000	--	7
	Site Preparation	Clear and grub site, level and compact, 1500 ft2 area	1	--	6,757	1	2
	Treatment Building	600 ft2 x 20 ft high metal building, (Butler-type); include concrete slab on grade, insulated with HVAC; include materials and installation.	1	--	18,934	2	2
	Utilities and Tie-ins	Building and process electrical, building plumbing and sewer/water tie-ins	1	10% of building	1,893	2	5
O&M	Operating	All materials and labor; excluding waste disposal	94.6Mgal/yr	$4.75/kgal	449,445/yr	--	7
	Maintenance	All materials and labor		3% of capital	40,233/yr	--	5
	Waste Disposal	Treatment residuals disposal as solid LLW; spent zeolite and filter wastes	4620 ft3/yr	$63/ft3	291,060/yr	--	8

Alternative 2
Pump and Treat - Treatment System
Reverse Osmosis

	Five Well System	Three Well System
Capital Cost: (Installed)		
Tanks and mixers	$22,935	$16,040
Feed pumps	$10,959	$7,664
RO package unit	$624,900	$437,035
RO pilot test by vendor	$14,000	$14,000
Waste evaporator	$720,000	$503,545
Waste solidification	$2,191	$1,532
Site preparation	$8,429	$5,895
Treatment building	$28,323	$19,808
Building utilities and tie-ins	$2,823	$1,974
Subtotal	$1,434,560	$1,007,494
Engineering @ 10%	$143,456	$100,749
Project Management @11%	$157,802	$110,824
Subtotal	$1,735,818	$1,219,068
Contingency @30%	$520,745	$365,720
Total Capital Cost	**$2,256,563**	**$1,584,789**
O&M Cost: (Annual)		
Chemicals	$23,863	$14,318
Operating and Maintenance	$168,800	$101,280
Electric Power	$99,474	$59,684
Waste disposal	$542,790	$325,674
Total O&M Cost	**$834,927**	**$500,956**
Present Worth	**$7,386,828**	**$4,662,948**

Pump and Treat

	System Module: Treatment Description: Reverse Osmosis - Five Well System						
Cost Type	**Component**	**Description**	**Quantity**	**Unit Cost**	**Total**	**Assumption**	**Source**
Capital	Flow Equalization Tank	6000 gal, carbon steel/w epoxy lining, vertical	1	--	14,259	1	2
	Equalization Tank Mixer	7.5 hp, vertical/impeller type, carbon steel	1	--	8,676	1	2
	Influent Feed Pump	10 hp, 500 gpm at 40 ft head, centrifugal, carbon steel	2	--	10,959	1	2
	Reverse Osmosis Package Unit	Vendor engineered and constructed, multi-stage, skid-mounted, package unit, 300 gpm incluing pre-filter units, high pressure pumps, RO membranes and vessels, chemical supply and metering systems	1	--	624,900	2	9
	Pilot Test	RO pilot test by vendor; complete	1	--	14,000	2	9
	Waste Evaporator	30 gpm vapor compression evaporator	1	--	720,000	2	10
	Waste Solidification	Mixing equipment for cement solidification of evaporator bottoms; 25 ft3/day	1	--	2,191	2	2
	Site Preparation	Clear and grub site, level and compact, 2000 ft2 area	1	--	8,429	1	2
	Treatment Building	1000 ft2 x 20 ft high metal building, (Butler-type); include concrete slab on grade, insulated with HVAC; include materials and installation.	1	--	28,323	2	2
	Utilities and tie-ins	Building and process electrical, building plumbing and sewer/water tie-ins	1	10% of building	2,823	2	5

System Module: Treatment
Description: Reverse Osmosis - Five Well System

Cost Type	Component	Description	Quantity	Unit Cost	Total	Assumption	Source
O&M	O&M for RO Unit	Operating, maintenance and electrical	1	108,000/yr	108,000/ yr	--	9
	Chemical for RO	Acid for pH control, hexametaphosphate for scale control	1	23,863/yr	23,863/ yr	--	12
	Operating for evaporator	Operating labor; 2 man-hours/day	730 hours/yr	$53.64/mh	39,200/ yr	1	--
	Maintenance for evaporator	Maintenance cost	1	3% of evap. capital	21,600/yr	--	5
	Electric power for evaporator	338 kw connected load	2.96 M kwh/yr	$0.0336/kwh	99,400/yr	--	10,6
	Evaporator waste disposal	Evaporator bottoms solidified with cement	7,990 ft3/yr	$63/ft3	503,370/ yr	--	8
	Drums for solid waste	Drums for containing the solidified evaporator bottoms	1,460/yr	$27/drum	39,420/yr	--	11
	Electric power for solidification mixer	1 hp motor	2,178 kwh/yr	$0.0336/kwh	74/yr	--	6

Alternative 2
Pump and Treat - Treated Water Disposal System
River Discharge

	Five Well System	Three Well System
Capital Cost: (Installed)		
Tanks	$14,259	$9,972
Transfer piping/leak detection	$14,661	$12,578
Effluent monitoring	$10,000	$10,000
Subtotal	$38,920	$32,550
Engineering @ 10%	$3,892	$3,255
Project Management @11%	$4,281	$3,581
Subtotal	$47,093	$39,386
Contingency @30%	$14,128	$11,816
Total Capital Cost	**$61,221**	**$51,201**
O&M Cost: (Annual)		
Operating labor	*	*
Maintenance	$1,167	$700
Total O&M Cost	**$1,167**	**$700**
Present Worth	**$68,392**	**$55,504**

* Included in treatment plant

Pump and Treat

System Module: Treated Water Disposal

Description: River Discharge - Five Well System

Cost Type	Component	Description	Quantity	Unit Cost	Total	Assumption	Source
Capital	Treated water sampling and collection tank	5000 gal, carbon steel/w epoxy lining, vertical; include level detection and control system	1	--	14,259	1	2
	Transfer piping (to river)	6-inch diameter, PVC, buried, double pipe, gravity flow; include valves, fittings, leak detection; include materials and installation	200 ft	--	13,328	1	4
	Piping leak detection	Materials and installation	--	10% of piping	1,333	--	5
	Instrumentation/Sr-90 monitoring	Materials and installation	--	Allowance	10,000	--	13
O&M	Operating labor	(*Included in treatment unit)	--	--	*	--	--
	Maintenance	Materials and labor	--	3% of capital	1,167/yr	--	5

Alternative 2
Pump and Treat - Treated Water Disposal System
N Area Crib

	Five Well System	Three Well System
Capital Cost: (Installed)		
Tanks	$14,259	$9,972
Transfer piping/leak detection	$215,985	$185,297
Pumps	$10,958	$7,664
Effluent monitoring	$10,000	$10,000
Disposal Crib (includes engin.)	$1,700,000	$1,188,926
Subtotal	$1,951,202	$1,401,859
Engineering @ 10%	$25,120	$21,293
Project Management @11%	$214,632	$154,205
Subtotal	$2,190,954	$1,577,357
Contingency @30%	$657,286	$473,207
Total Capital Cost	**$2,848,241**	**$2,050,564**
O&M Cost: (Annual)		
Operating labor	*	*
Maintenance	$7,535	$4,521
Electric Power	$1,388	$833
Total O&M Cost	**$8,923**	**$5,354**
Present Worth	**$2,903,069**	**$2,083,461**

* Included in treatment plant

Pump and Treat

System Module: Treated Water Disposal

Description: N Area Crib - Five Well System

Cost Type	Component	Description	Quantity	Unit Cost	Total	Assumption	Source
Capital	Treated water sampling and collection tank	6000 gal, carbon steel/w epoxy lining, vertical; include level detection and control system	1	--	14,259	1	2
	Transfer piping (to crib)	6-inch diameter, Sch 40 PVC, buried, double pipe; include valves, fittings, leak detection; include materials and installation	3000 ft	--	215,985	1	4
	Transfer pump	10 hp, 500 gpm at 40 ft head, centrifugal, carbon steel; include materials, installation and electrical	2	--	10,958	1	2
	Instrumentation/Sr-90 monitoring	Materials and installation	1	Allowance	10,000	1	13
	Disposal Crib	Crib, 300 gpm; include design, materials, and construction	1	--	1,700,000	2	14
O&M	Operating labor	(*Included in treatment plant)	--	--	*	--	--
	Maintenance	Materials and labor	--	3% of capital (excluding crib)	7,536/yr	--	5
	Power	Electric power for pump	41,300 kwh/yr	$0.0336/kwh	1,388/yr	--	6

Alternative 2
Pump and Treat - Treated Water Disposal System
N Area Injection Wells

	Five Well System	Three Well System
Capital Cost: (Installed)		
Tanks	$14,259	$9,972
Transfer piping/leak detection	$215,985	$185,297
Pumps	$10,959	$7,664
Effluent monitoring	$10,000	$10,000
Injection Wells	$466,440	$326,213
Subtotal	$717,643	$539,147
Engineering @ 10%	$71,764	$53,915
Project Management @11%	$78,941	$59,306
Subtotal	$868,348	$652,368
Contingency @30%	$260,504	$195,710
Total Capital Cost	**$1,128,852**	**$848,079**
O&M Cost: (Annual)		
Operating labor	*	*
Maintenance	$7,536	$4,522
Electric Power	$1,388	$833
Total O&M Cost	**$8,924**	**$5,354**
Present Worth	**$1,183,687**	**$880,979**

* Included in treatment plant

Pump and Treat

System Module: Treated Water Disposal

Description: N Area Reinjection - Five Well System

Cost Type	Component	Description	Quantity	Unit Cost	Total	Assumption	Source
Capital	Treated water sampling and collection tank	6000 gal, carbon steel/w epoxy lining, vertical; include level detection and control system	1	–	14,259	1	2
	Transfer piping (to injection wells	6-inch diameter, Sch 40 PVC, buried, double pipe; include valves, fittings, leak detection; include materials and installation	3000 ft	–	215,985	1	4
	Transfer pump	10 hp, 500 gpm at 40 ft head, centrifugal, carbon steel; include materials, installation and electrical	2	--	10,959	1	2
	Instrumentation/Sr-90 monitoring	Materials and installation	--	Allowance	10,000	1	13
	Injection Wells	6-inch diameter, 104 ft total depth, stainless steel, install by cable tool drilling; costs include all materials, mob/demob, drilling labor, logging, well development, waste disposal, equipment decon	312 ft	$1495/ft	466,440	--	1
O&M	Operating labor	(*Included in treatment plant)	--	–	*	–	--
	Maintenance	Materials and labor	--	3% of capital (excluding injection wells)	7,535/yr	--	5
	Power	Electric power for pump	41,300 kwh/yr	$0.0336/kwh	1,388/yr	–	6

Alternative 2
Pump and Treat - Treated Water Disposal System
200 Area Crib

	Five Well System	Three Well System
Capital Cost: (Installed)		
Tanks	$14,259	$9,972
Transfer piping/leak detection	$4,116,596	$4,116,596
Pumps	$10,959	$7,664
Effluent monitoring	$10,000	$10,000
Disposal Crib (includes engin.)	$1,700,000	$1,188,926
Subtotal	$5,851,814	$5,333,159
Engineering @ 10%	$415,181	$414,423
Project Management @11%	$643,700	$586,647
Subtotal	$6,910,695	$6,334,229
Contingency @30%	$2,073,208	$1,900,269
Total Capital Cost	**$8,983,903**	**$8,234,498**
O&M Cost: (Annual)		
Operating labor	*	*
Maintenance	$124,554	$74,732
Electric Power	$9,095	$5,457
Total O&M Cost	**$133,649**	**$80,189**
Present Worth	**$9,805,119**	**$8,727,227**

* Included in treatment plant

Pump and Treat

System Module: Treated Water Disposal

Description: 200 Area Crib - Five Well System

Cost Type	Component	Description	Quantity	Unit Cost	Total	Assumption	Source
Capital	Treated water sampling and collection tank	6000 gal, carbon steel/w epoxy lining, vertical; include level detection and control system	1	--	14,259	1	2
	Transfer piping (to 200 Area)	8-inch diameter, Sch 40 carbon steel, buried, double pipe; include valves, fittings, leak detection; include materials and installation	48,000 ft	--	4,116,596	2	4
	Transfer pump	40 hp, 300 gpm at 350 ft head, centrifugal, carbon steel; include materials, installation and electrical	2	--	10,959	1	2
	Instrumentation/Sr-90 monitoring	Materials and installation	--	Allowance	10,000	1	13
	Disposal Crib (at 200 Area)	Crib, 300 gpm; include design, materials and construction	1	--	1,700,000	2	14
O&M	Operating labor	(*Included in treatment plant)	--	--	*	--	--
	Maintenance	Materials and labor	--	3% of capital (excluding crib)	124,554/yr	--	5
	Power	Electric power for pump	270,700 kwh/yr	$0.0336/kwh	9,095/yr	--	6

Alternative 3
Vertical Barrier
Slurry Wall

Capital Cost: (Installed)	
Slurry wall, subcontractor installed by deep soil mixing	$6,200,000
Testing (incl. engineering)	$200,000
Engineering @10%	$620,000
Project Management @11%	$682,000
Subtotal	$7,702,000
Contingency @30%	$2,310,600
Total Capital Cost	**$10,012,600**
O&M Cost: (Annual)	
Operating labor	0
Maintenance	0
Electric Power	0
Total O&M Cost	**$0**
Present Worth	**$10,012,600**

Slurry Wall At River

Cost multiplier =	(52 ft depth/104 ft depth)^0.7 = 0.616	
Cost =	10.01 X 0.616	6,167,762
Add. for Wetlands Analysis		200,000
Total Cost		**$6,367,762**

Vertical Barrier

System Module: Slurry Wall
Description: Install By Deep Soil Mixing

Cost Type	Component	Description	Quantity	Unit Cost	Total	Assumption	Source
Capital	Slurry wall installed by deep soil mixing	Vendor engineered and constructed, 2800 ft long, average 104 ft depth, includes materials and installation	291,200 ft2	$20.60/ft2	6,000,000	2	16
	Auger replacement	Replace contaminated/broken augers	--	Allowance	200,000	2	--
	Field testing	Develop appropriate slurry mixtures and demonstrate constructability in Hanford soils	--	--	200,000	2	16

Alternative 2
Hydraulic Control
Extraction Wells

Capital Cost: (Installed)	
Pumping Wells	$716,034
Transfer piping	$698,087
Pumps	$39,778
Effluent monitoring	$10,000
Subtotal	$1,463,899
Engineering @ 10%	$146,390
Project Management @11%	$161,029
Subtotal	$1,771,318
Contingency @30%	$531,395
Total Capital Cost	**$2,302,713**
O&M Cost: (Annual)	
Operating labor	$39,157
Maintenance	$22,436
Electric Power	$9,510
Total O&M Cost	**$71,103**
Present Worth	**$2,739,610**

Hydraulic Control

System Module Groundwater Extraction
Description Hydraulic Control

Cost Type	Component	Description	Quantity	Unit Cost	Total	Assumption	Source
Capital	Pumping Wells	11 wells, 8-inch diameter, 114 ft total depth, stainless steel, install by cable tool drilling; costs include all materials, mob/demob, drilling labor, logging, well development, waste disposal, equipment decon	1254 ft	$571/ft	716,034		
	Pumps	5 hp, 75 gpm at 100 ft head, submersible, stainless steel; costs include materials and installation	4	--	14,283		
	Pumps	5 hp, 100 gpm at 100 ft head, submersible, stainless steel; costs include materials and installation	5	–	17,853		
	Pumps	7.5 hp, 150 gpm at 100 ft head, submersible, stainless steel; costs include materials and installation	2	--	7,642		
	Transfer piping to river	16-inch, single wall PVC, buried below frost line; costs include pipe materials, valves, valve boxes and fittings, trenching, installation	8000 ft	–	698,087		
	Instrumentation/Sr-90 monitoring	Materials and installation	–	Allowance	10,000		
O&M	Operating	Assume 2 man-hours/day	730 mh/yr	$53.64/mh	39,157/yr		
	Labor	Materials and labor	--	3% of capital (excluding wells)	22,436/yr		
	Elect. Power	Power for pumps; annual cost	283,054 kwh/yr	$0.0336/kwh	9,510/yr		

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